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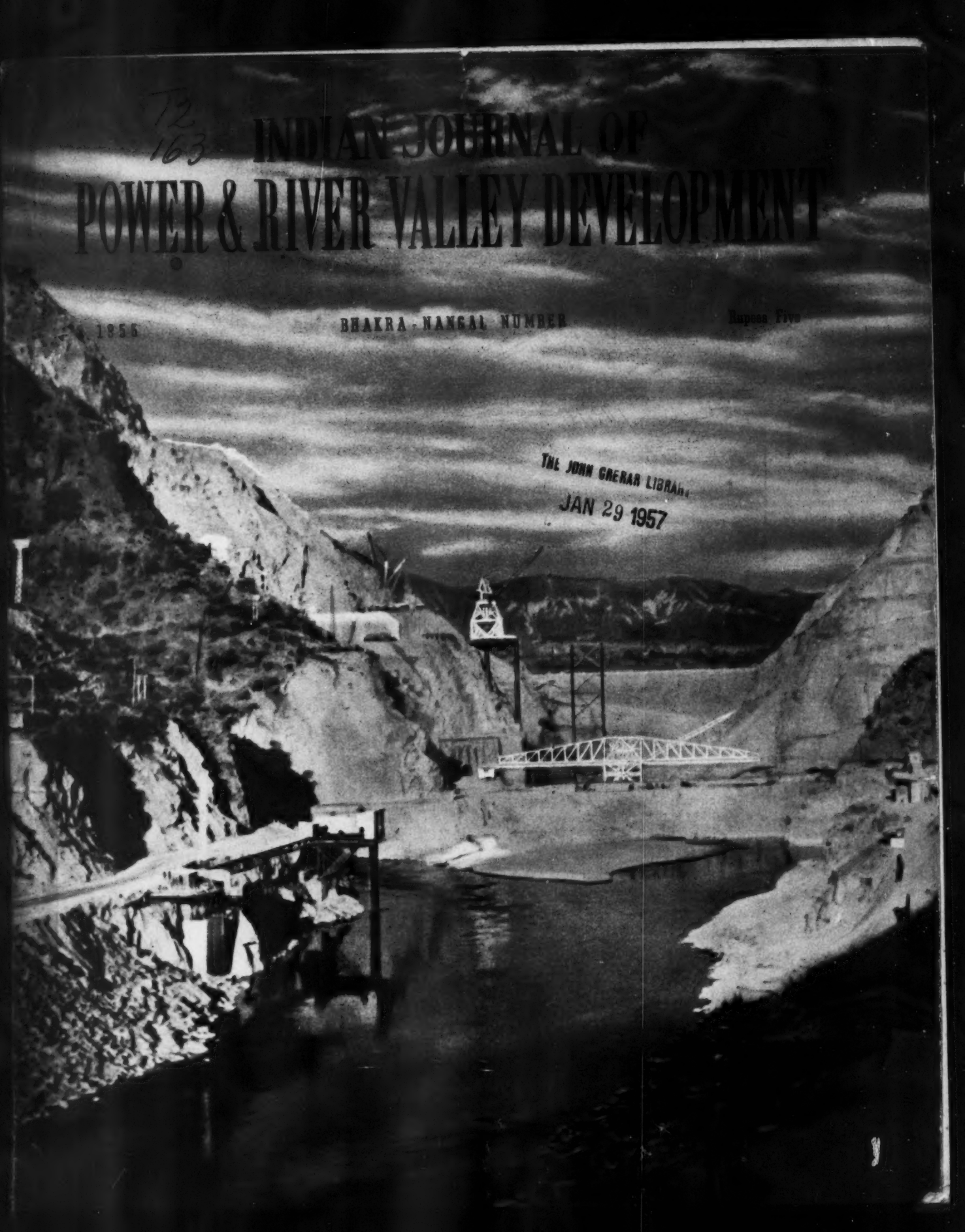

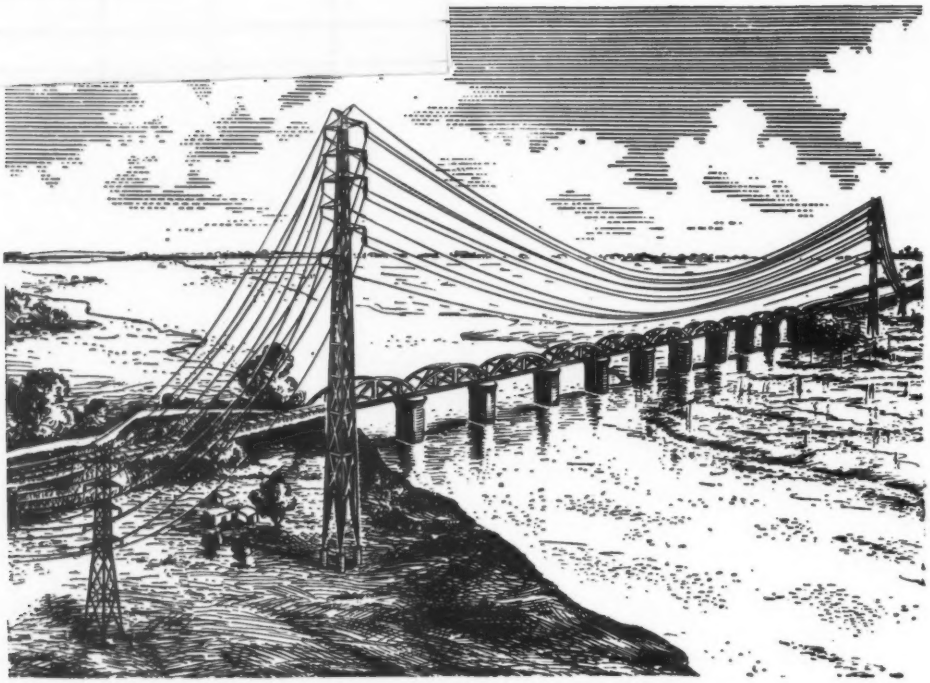

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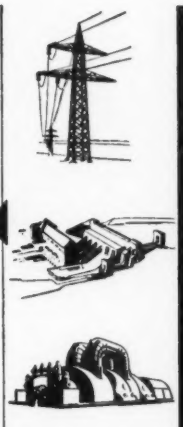

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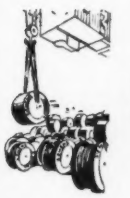

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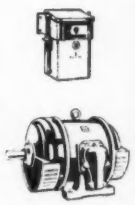

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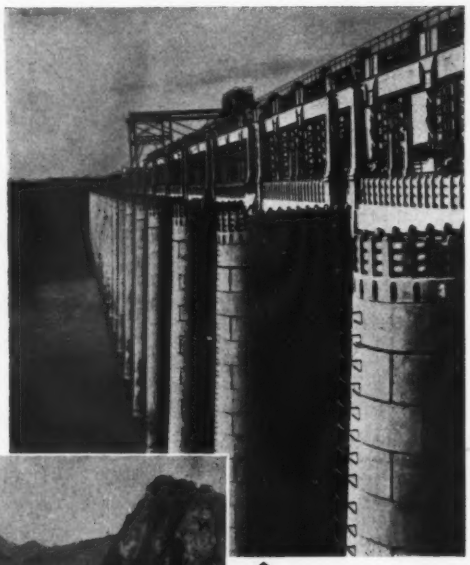

▲ Nangal Barrage. Down-stream view from the left bank.

Sirsa Aqueduct View showing Nangal Hydel Channel crossing the Sirsa River. Mark the R. C. inverted T-beams, road, and foot bridges. ▼

▲ A view of the concrete-lined Nangal Hydel Channel upstream of Lohand Syphon.

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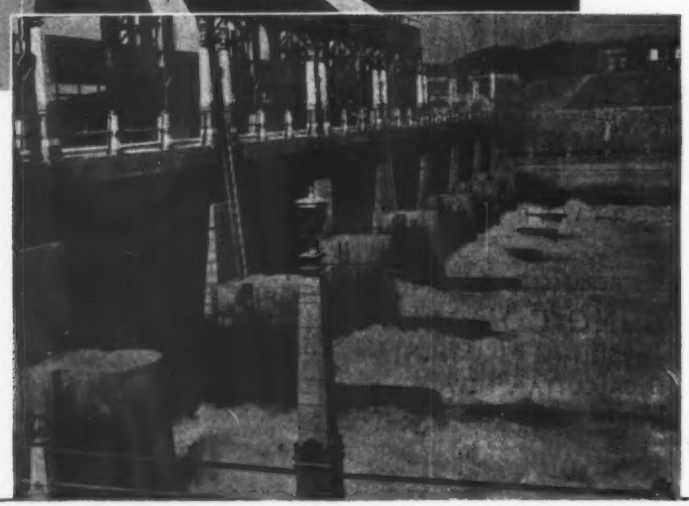

◀ Nangal Hydel channel Head Works. View from down stream.

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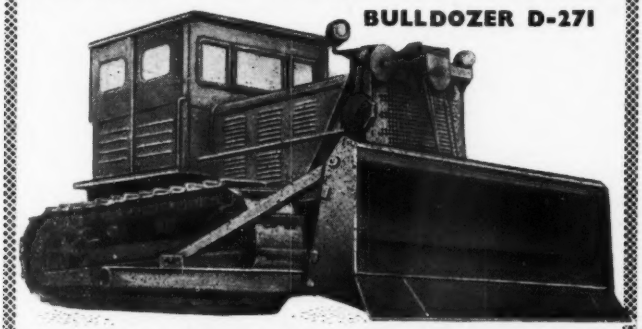

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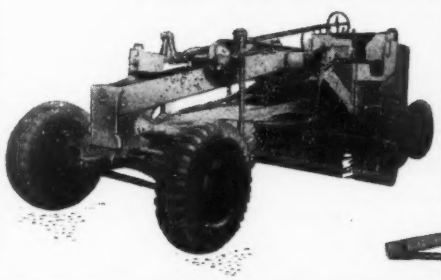

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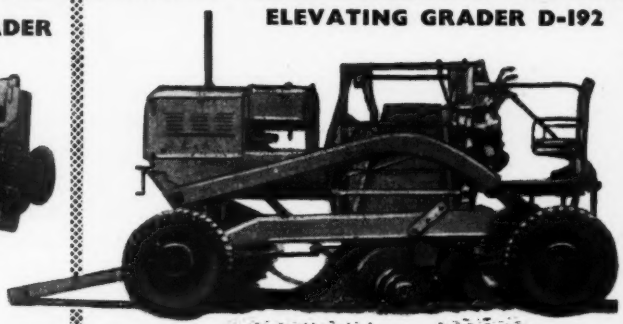

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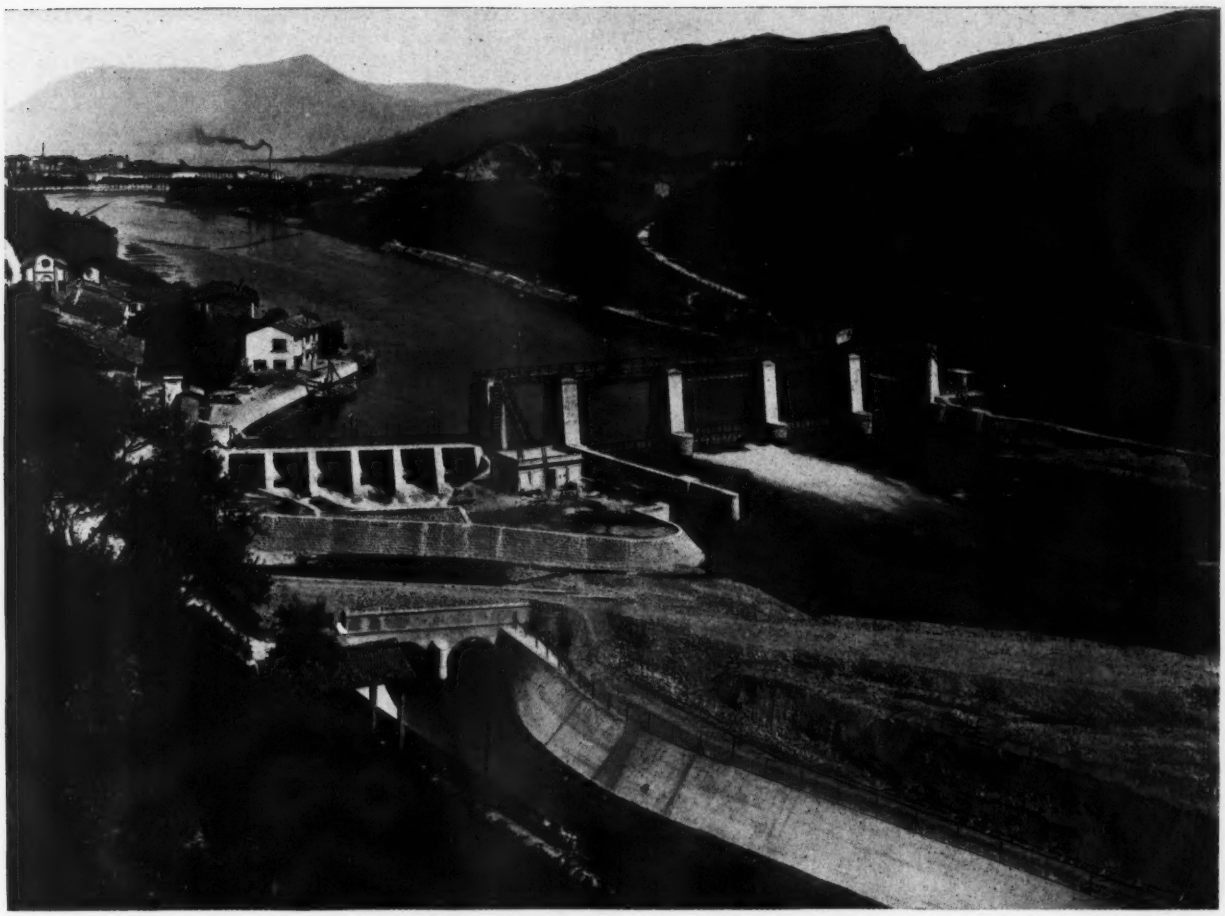

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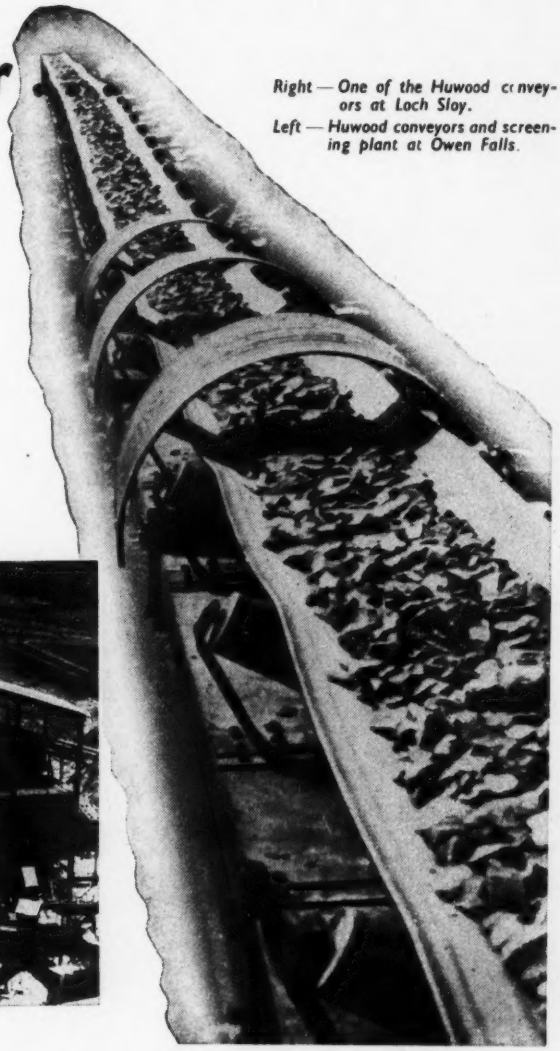

Right — One of the Huwood conveyors at Loch Sloy.
Left — Huwood conveyors and screening plant at Owen Falls.

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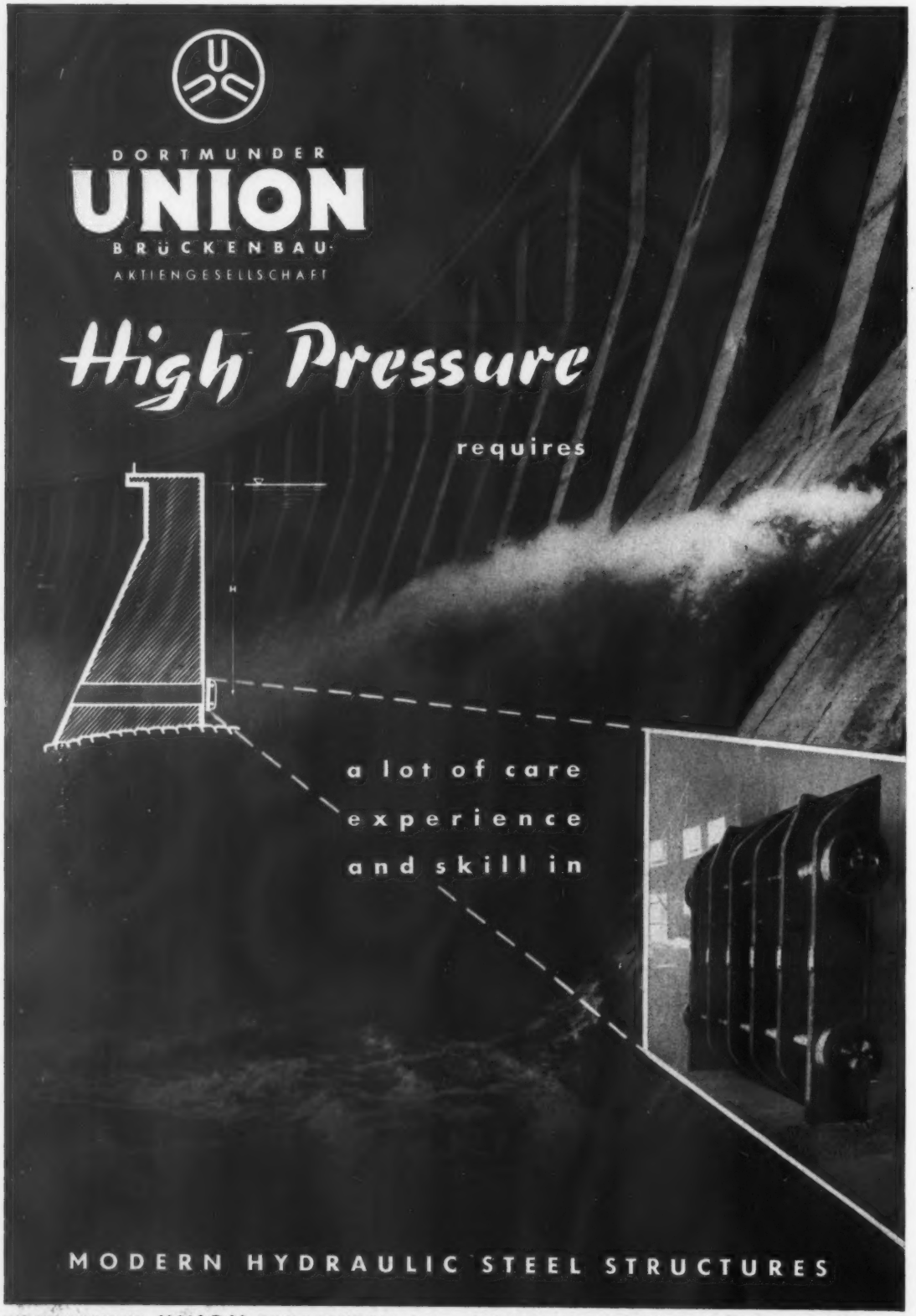

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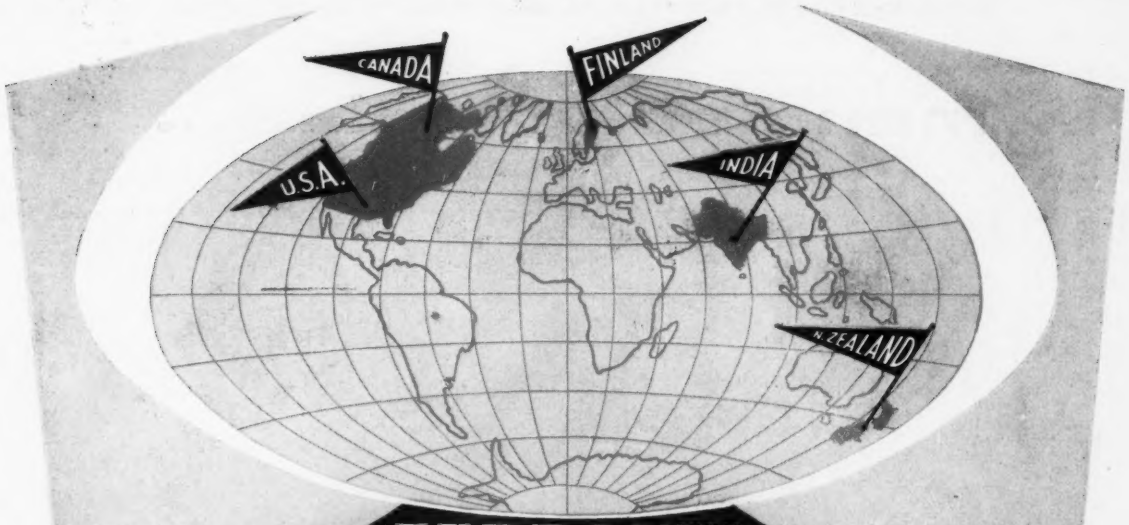

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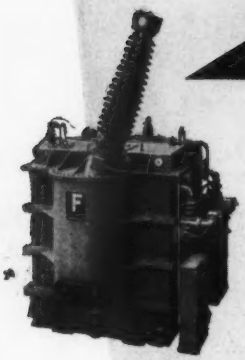
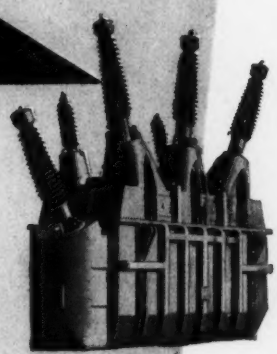


U.S.A. Nine 33,333 kVA, 230,000 volt single-phase Ferranti transformers are being supplied to the U.S. Army Corps of Engineers for the Garrison Dam Project, North Dakota, U.S.A. Three, forming the first 100,000 kVA bank, have been shipped.

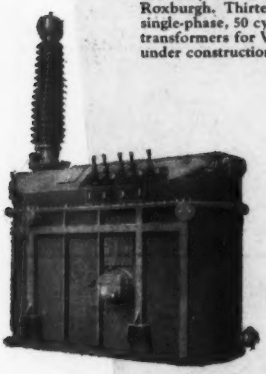
FINLAND Six 230,000 volt, three-phase Ferranti transformers have been ordered by the Imatra Power Company, Finland, for the Hikia Transforming Station and the Pyhäkoski Generating Station. Five are now in commission.

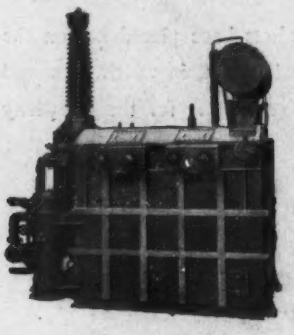


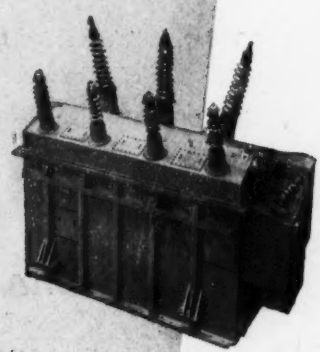
NEW ZEALAND Twenty-six Ferranti large power transformers have been ordered by the State Hydro-Electric Department of New Zealand. Thirteen 14,800 kVA, single-phase, 50 cycles, 11/220 kV transformers have already been supplied to Roxburgh. Thirteen 9,259 kVA, single-phase, 50 cycles, 11/220 kV transformers for Whakamaru are under construction.

CANADA Four 71,000 kVA, 301,400 volt single-phase Ferranti generator transformers and three 37,000 kVA, 275,000 volt step-down Ferranti transformers have been supplied to the Aluminum Company of Canada Limited for the Alcan Project at Kemano and Kitimat, British Columbia.

INDIA Three Ferranti 20,000 kVA, OFB, 3-phase, 50 cycles, 132/33.66 kV Transformers with on-load tap changing gear and two Ferranti 10,000 kVA, ON/OB, 3-phase, 50 cycles, 132/33 kV transformers with on-load tap changing gear have been supplied for the Damodar Valley Power Scheme in India.







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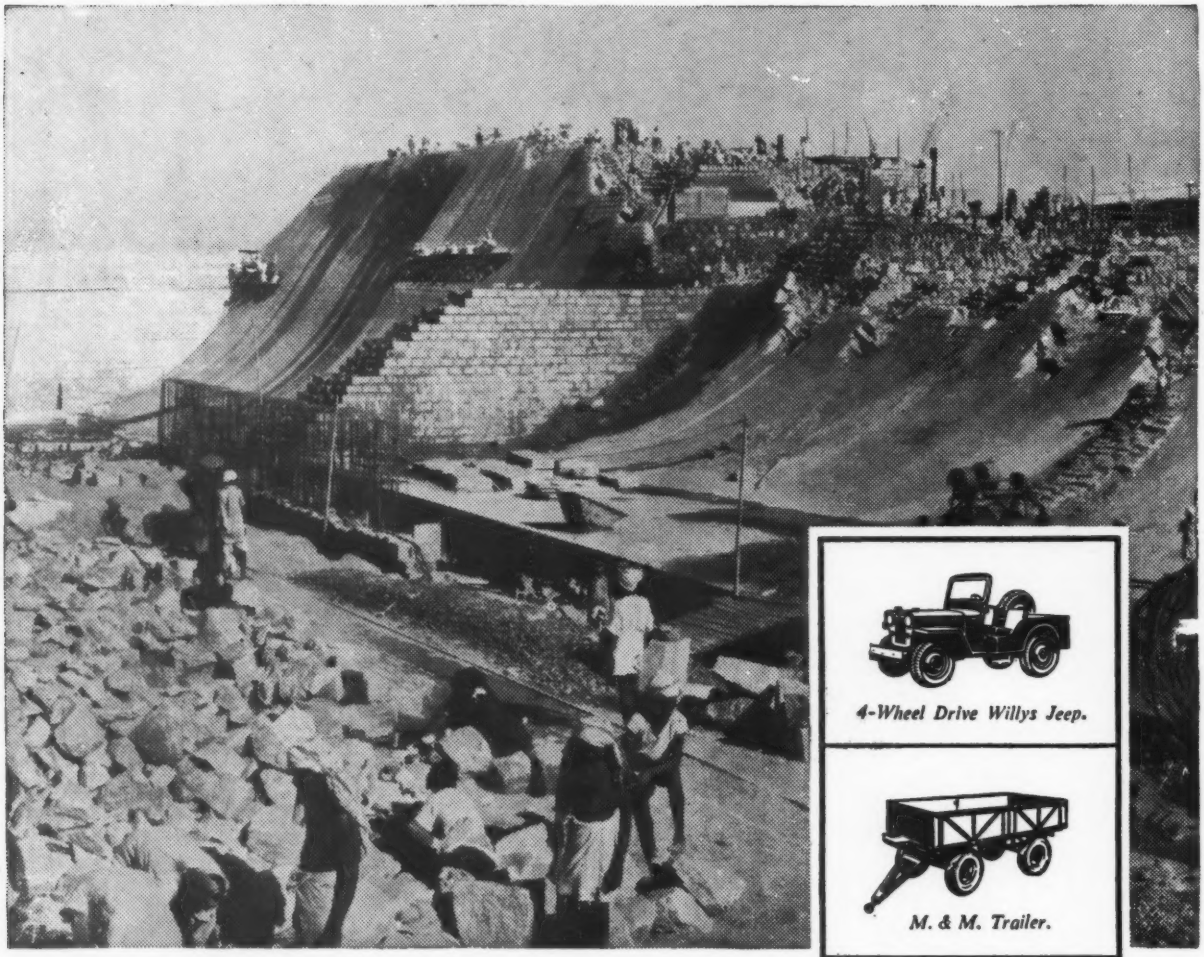

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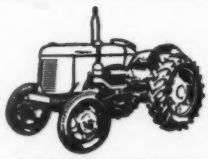

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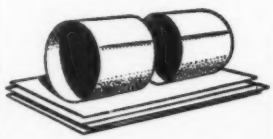

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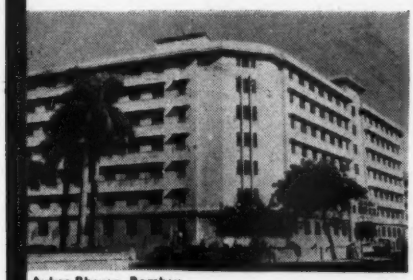

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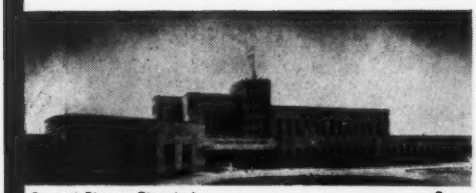

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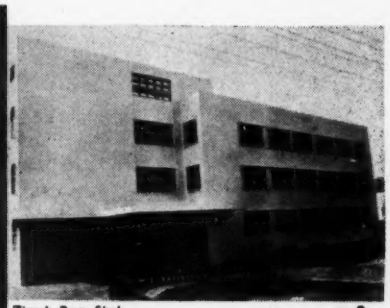

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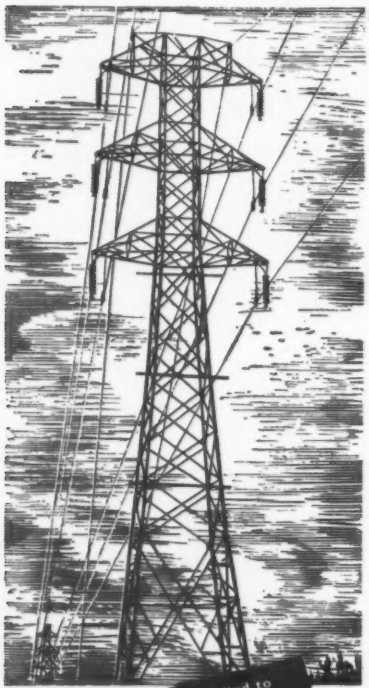

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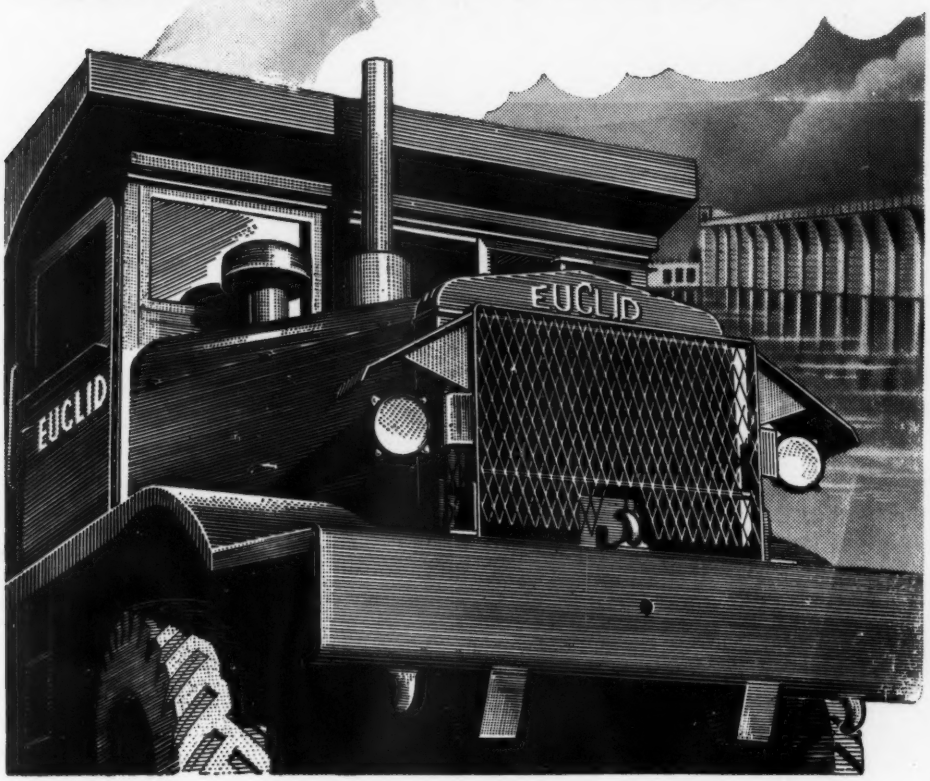

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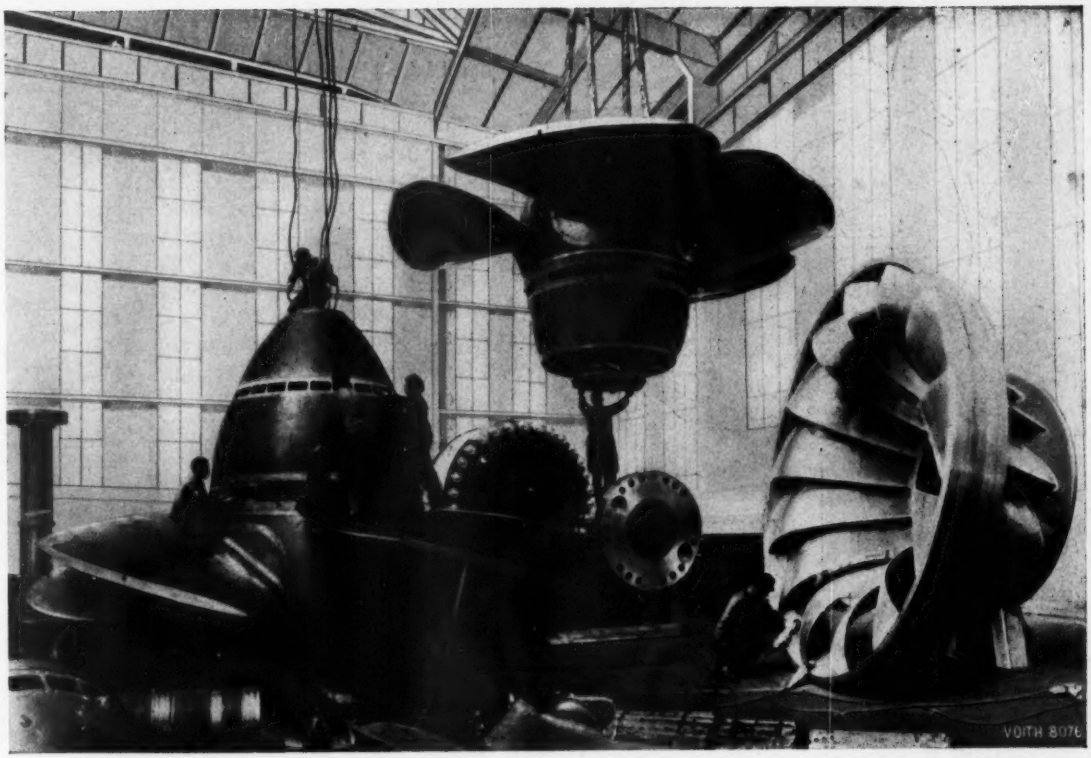

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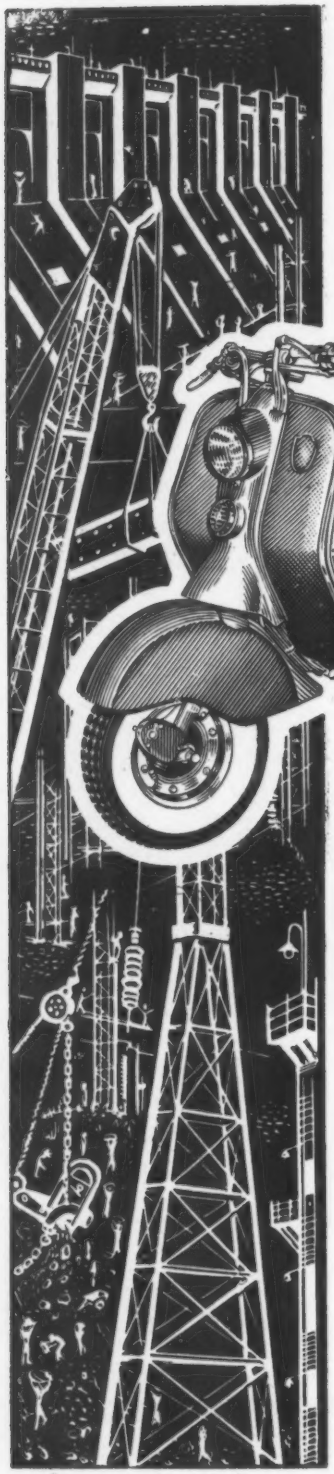

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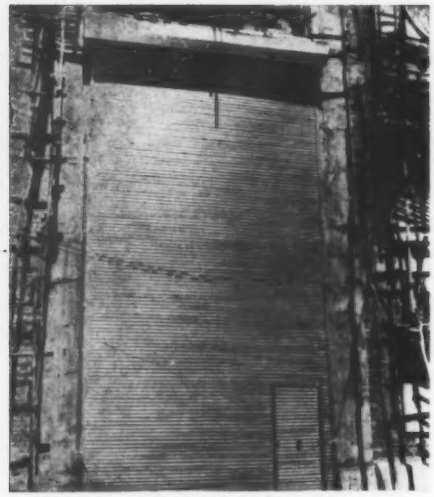

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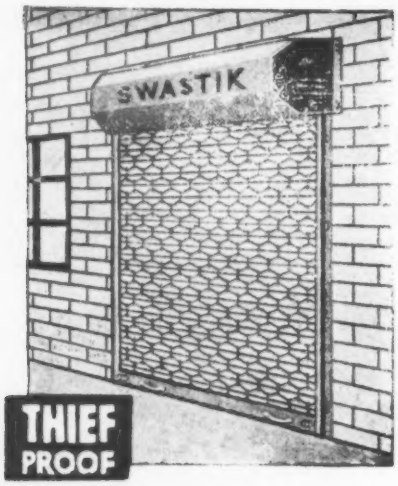

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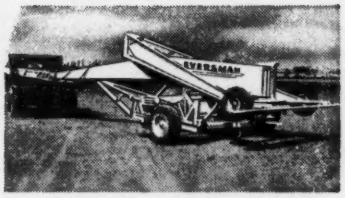

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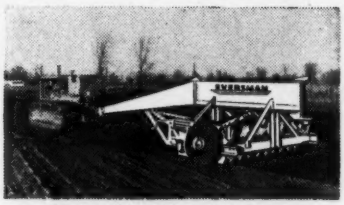

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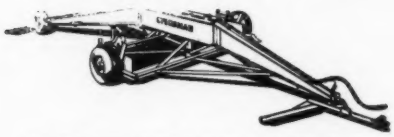

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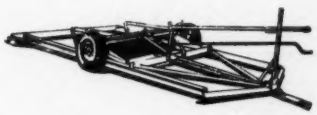
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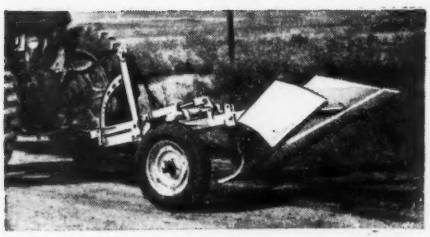

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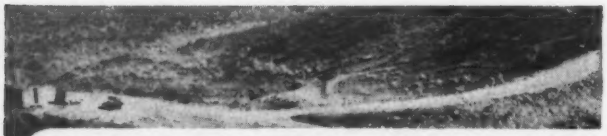

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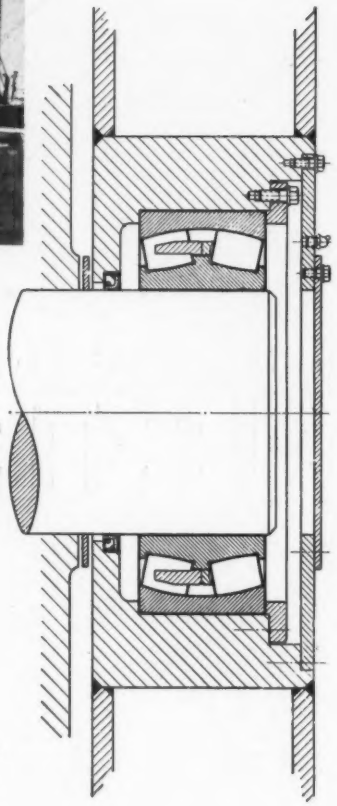

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For

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Substations of the

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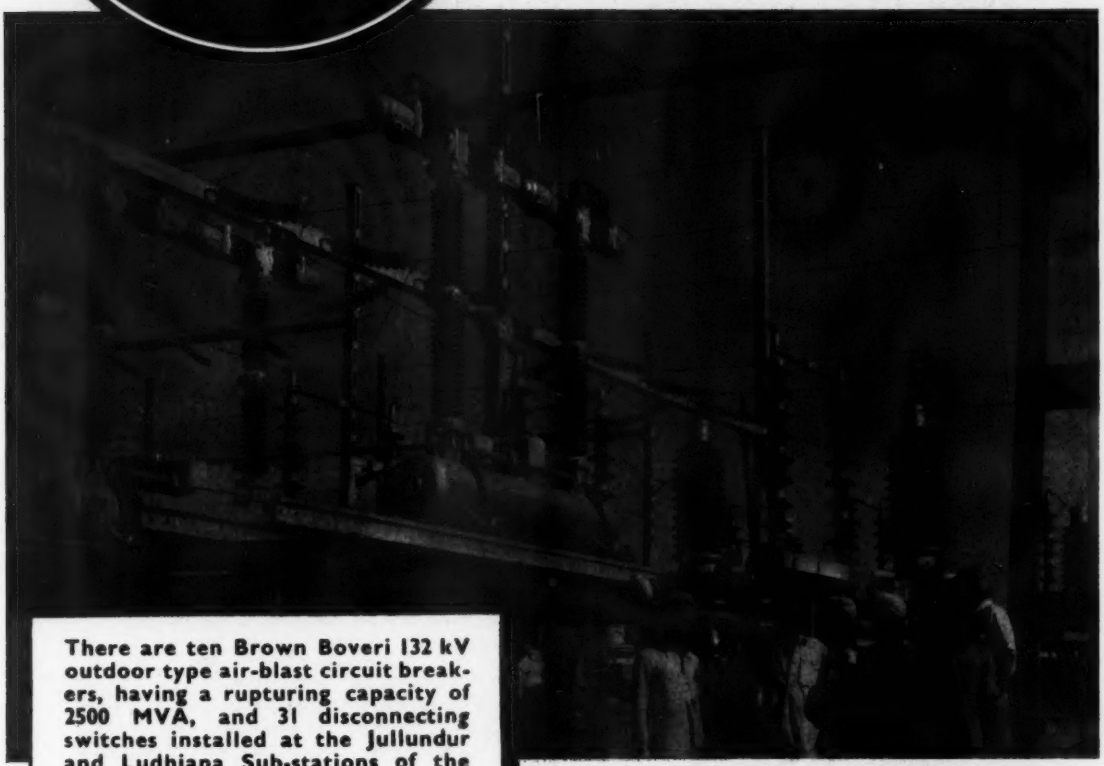

There are ten Brown Boveri 132 kV outdoor type air-blast circuit breakers, having a rupturing capacity of 2500 MVA, and 31 disconnecting switches installed at the Jullundur and Ludhiana Sub-stations of the Nangal Power Project.

Further, all the 33 kV indoor type air-blast circuit breakers mounted in outdoor kiosks, 11 kV oil circuit breakers and the associated current and potential transformers as well as the control gear are also of Brown Boveri make supplied by Voltas Ltd.

The photograph shows parts of the equipment installed at the Ludhiana Sub-station.

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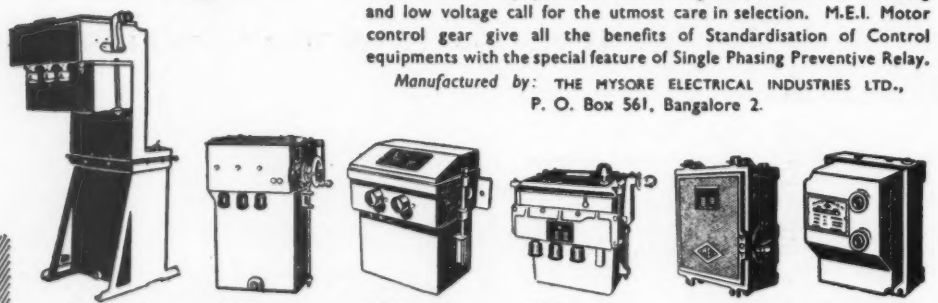

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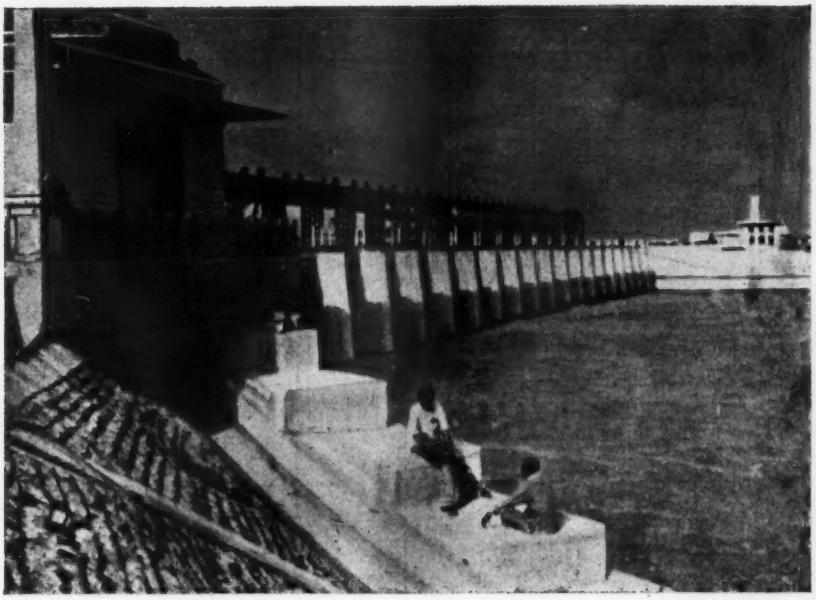

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Petroleum's contribution to the building of India's river valley projects is certainly impressive. It serves a number of essential requirements; and the Bhakra-Nangal authorities have used and are still using large quantities of such petroleum products as High Speed Diesel Oil (for heavy earth-moving machinery), Light Diesel Oil (for power-houses), Motor Spirit, Lubricants and Bitumen. To make the supply of some of these products easy, Burmah-Shell have built pumps at Bhakra-Nangal work sites.

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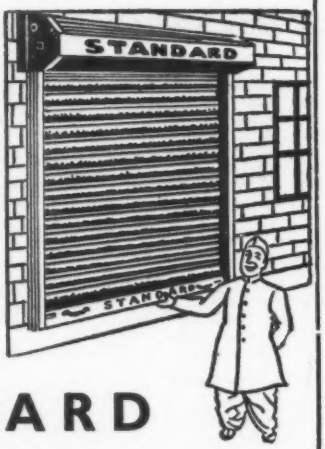

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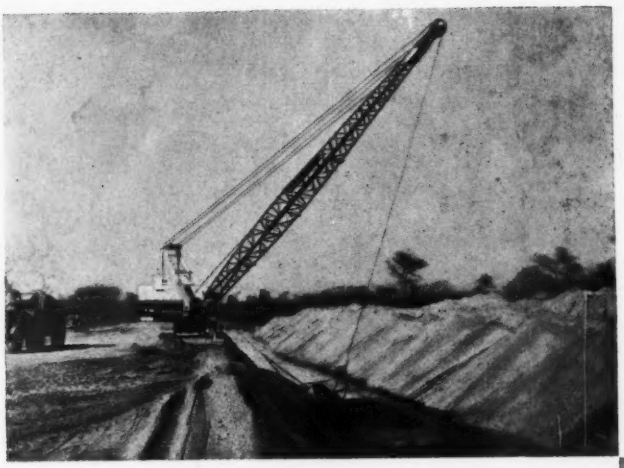

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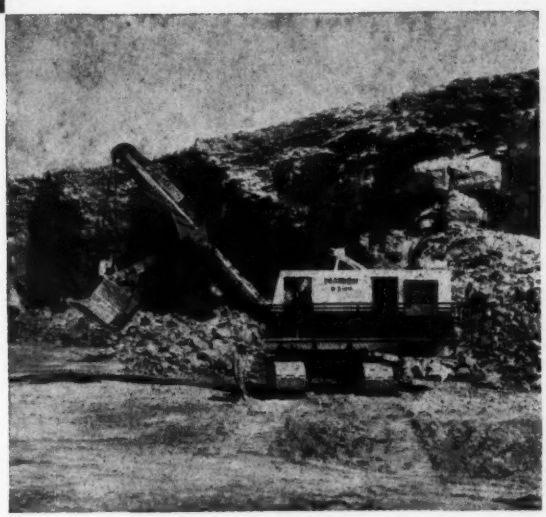

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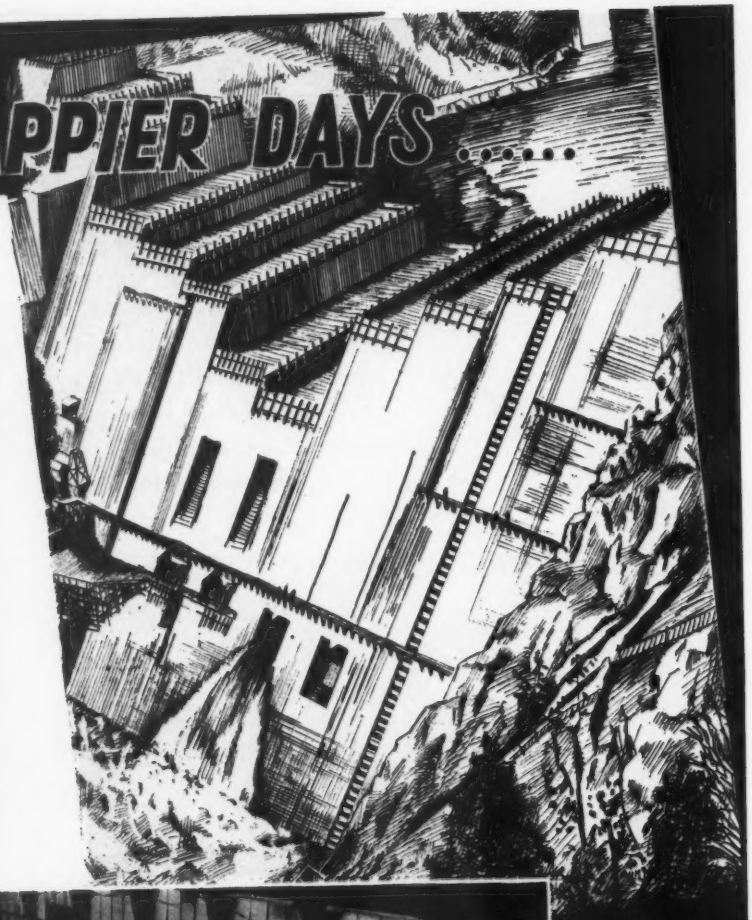

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A MONTHLY DEVOTED TO DEVELOPMENT OF POWER & WATER RESOURCES IN ASIA

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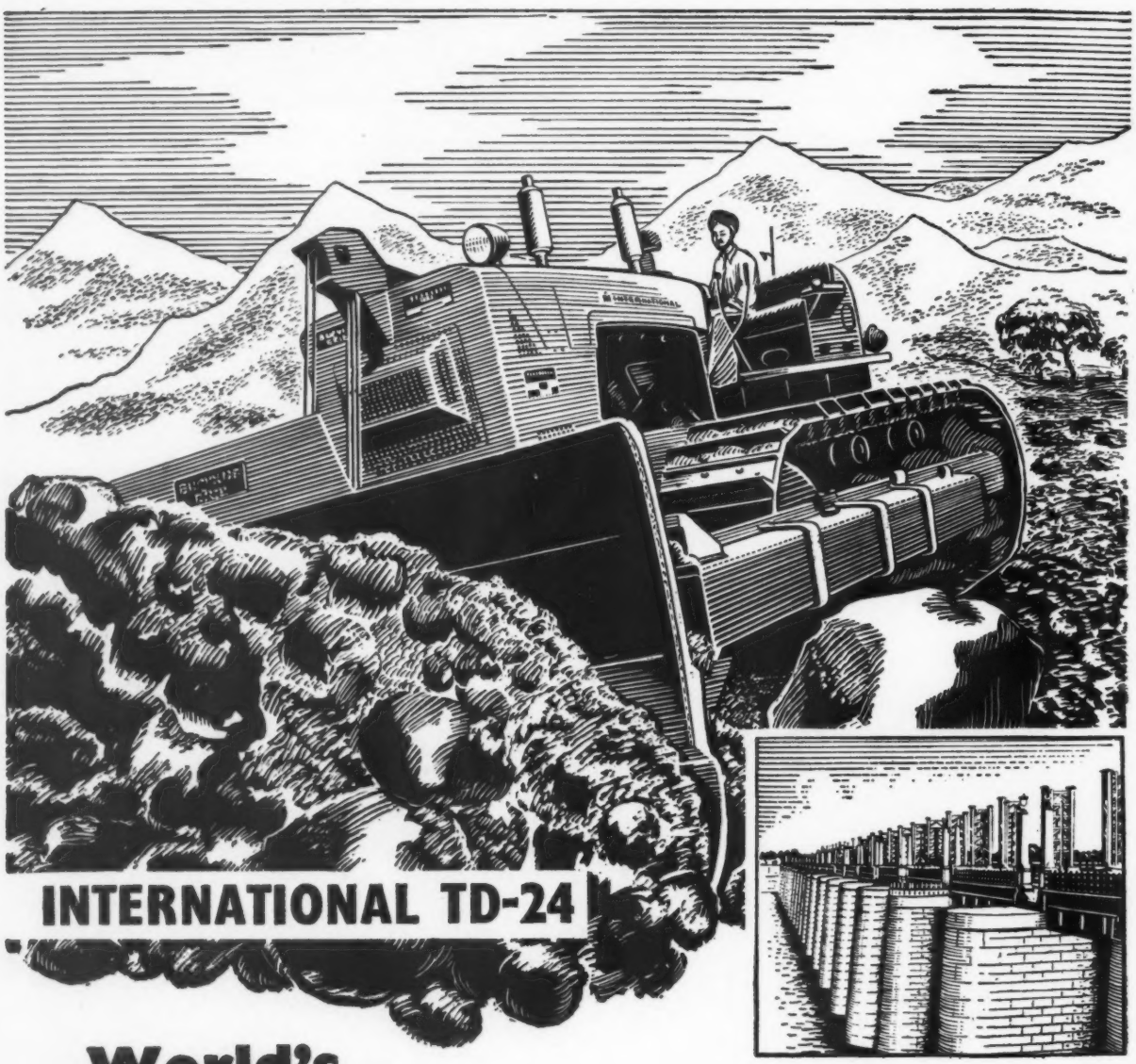

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Introduction

There is an increasing demand for technical literature written in easy language. It must be understandable by the layman, who forms the bulk of the public for whom development projects are being undertaken. At present there is great dearth of such literature. It is not possible to get a connected story about a project even by reference to half a dozen departmental reports.

At attempt to fill this gap is being made by this Journal. For the last five years, some pioneering work in the field of technical literature has been already presented to its readers.

The Bhakra Nangal Project lends itself to such a proposition because it touches the widest cross-section of people in the North West India region. It is common enough to see technical articles and side lights on the project from various authorities, but no body has yet taken the responsibility to write up the entire story in a connected form. The technical reports are far too technical for the common reader. Even press correspondents have often been caught making misstatements which had to be later corrected.

The only remedy for such a situation is that technical journals should regard it their function to prepare special write-ups in which the facts are given in a straightforward and simple manner, preferably illustrated by charts and photographs. But there has been a lack of suitable technical writers who can also cater to the popular demand.

It has been acknowledged all round that the stupendous programmes of construction that have been laid before the country can only be implemented by the fullest association of the people with the Government authorities. That there is enough public interest for such matters cannot be denied, but no systematic effort has been made for the sustenance of such interest or for its direction in right channels. Now and again some controversy raises its head, but the contending parties hardly ever put forth the subject in a clear and self-contained manner to show which of the views is correct. Even such important issues as the rate of development of hydro-electric power or load forecasts for various regions are not clearly discussed. Yet a proper development of electric power or setting up of factories can only be brought about through the fullest cooperation and initiative of the public. If the authorities incharge of projects and other agencies which have to do something with the project in any phase were to put out literature to educate public opinion, the success of the undertakings would be accomplished to a much higher level in a much shorter time.

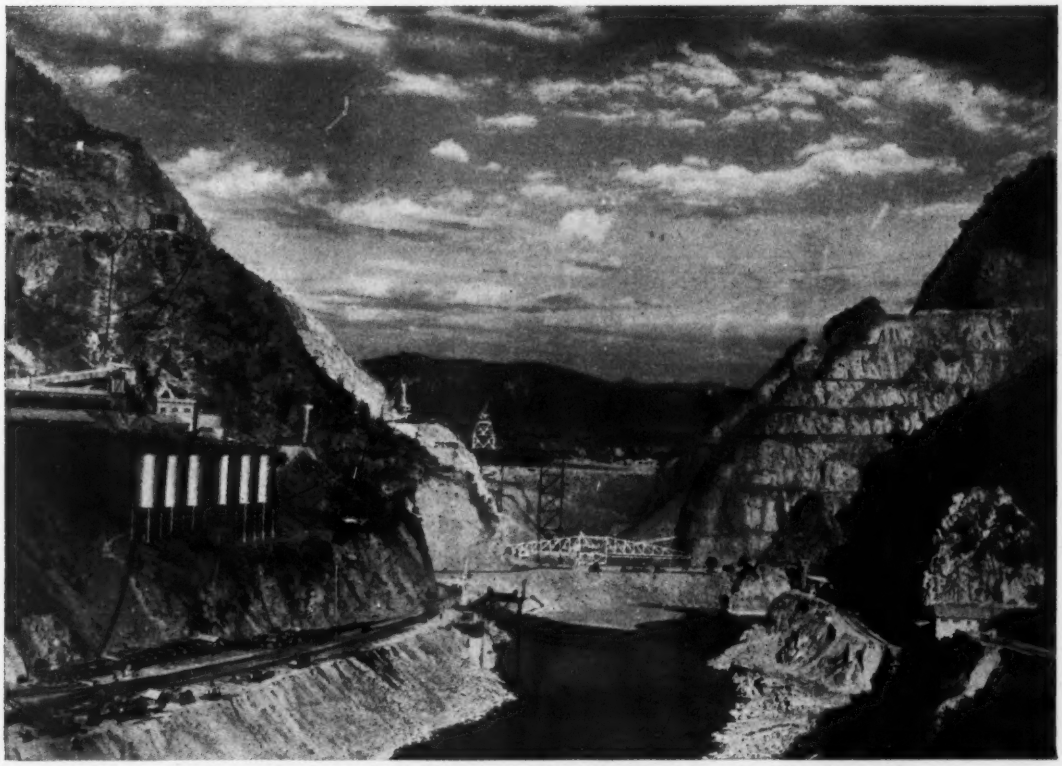
In other countries where great progress in development projects has been made in the last few decades, there is no dearth of literature, brochures and pamphlets from which the man in the street is able to get all that he wants to know about the projects. With proper publicity a healthy climate of opinion is created, and the furtherance of the project is ensured because constructive criticism from all quarters gets incorporated in the scheme and the best practicable decisions are formulated and implemented. In this country we are yet at the threshold of development programmes, but the people are unable to play their full part partly because of lack of information. It is not that the people here are less anxious to make their contribution, but the conditions are so different that they do not know the mechanism in sufficient detail to be able to make their suggestions in time. The result is a few disjointed questions in the State Legislatures and Union Parliament. The answers given are brief and they generally justify Government actions without disclosing the background. The full object of the exchange of views is not fulfilled, and people are left to make their best guess as to the why and how of many an important matter.

For the last three years, the Ministry of Irrigation and Power have introduced a novel institution called the Engineers' Seminar. In addition, the Union Minister has taken every opportunity of convening informal meetings between the regional M.Ps. and the Government officials concerned in order to clarify the position regarding the programmes and problems pertaining to the various regions. In order to take full advantage of the opportunity, Members of Parliament have expressed the greatest desire for being

I: River Sutlej at Bhakra in its primeval splendour—the site as it was

II: Exploratory Drilling in river bed with drills mounted on pontoons—the first invasion

III: Excavation with heavy machines in progress in pit-area—the struggle with nature



IV: Concreting of the Dam begins—man lays the foundation for changing nature

supplied with literature bearing on the project giving the salient facts without undue technicalities. It will be admitted on all hands that such exchanges of views have been most helpful for the proper assimilation of the factors which have influenced the success or failure of the individual projects. It is, therefore, high time that there may be the fullest attention given to the production of literature in which the factual information is correctly presented, in a brief and handy form, for the benefit of the layman and his representatives in Parliament.

It is also upto the authorities who deal with planning, design and execution of projects, that they explain to the layman the implication of the various technical factors involved. There is no doubt that deeper technicalities would be tough reading for the common man, but the broad features of various alternative schemes are definitely within his range of interest. It is therefore upto the technical people that they should bring out the salient aspects of their projects in order to enthuse the public who are within the zone of influence of the project. There will be quite a rich reward for this in the shape of intelligent co-operation from the public for which there is no substitute and which cannot be purchased by payment of any price.

The next point is the form in which such data needs to be presented. If we scrutinize the columns of modern periodicals on planning, costing or construction, we cannot but help being struck by the graphic effect of the pictures that are used in illustration of the text. Similarly the projects of the country need to be explained to the people with the help of easily intelligible graphs and charts. One has only to visit the exhibitions that are being shown all over the country to convince oneself that this form of educative propaganda is now accepted as one of the best modes of approach to the people. In fact the daily press is now carrying more head-lines on the economic revolution through which India is undergoing rather than communal or political issues, which have ceased to command the interest that they aroused in the pre-independence period. This is a sign of awakening amongst the people whose aspirations are now diverted towards a constructive trend rather than mere academic discussion of unproductive controversies.

The Second Five Year Plan is facing the country with a challenge much bigger than the challenge of the First Five Year Plan. In the first plan, a good many mistakes and omissions were inevitable. The authorities could turn round and put in the plea of inexperience and want of full data in their explanations and defence. This justification is no longer going to command respect or authority. It is, therefore, in the best interest of all concerned that the common man be associated in the work of the projects, and made to feel the importance of his constribution. It is more through intelligent understanding and contructive criticism that the tone and the efficiency of the performance on development projects will be enlivened.

The *Indian Journal of Power and River Valley Development* has ventured to fill the gap in this urgent field. Since official sources are difficult of access and the officers are far too busy with their direct executive and administrative duties, the Journal's special staff writers have taken the onerous burden upon themselves with the help of the great bulk of literature that has already appeared in the Press in one form or other as well as by making special visits to the project area and having personal discussions with engineers in charge. The views set forth are personal to the writers and do not bind the Government or the Journal in any way. The Journal keeps an open mind, as development projects are in a dynamic stage. A scientific and objective outlook is the best guarantee for progress, within the vast field of development of power and irrigation on our various River Valley Projects—of which Bhakra Nangal is an illustrious pioneer. We hope that this number will not only be highly educative but will also raise a number of important questions of policy in the realm of river valley development that needs to be discussed much more widely than hitherto; we shall consider our efforts amply rewarded if this issue promotes this greater public awareness.

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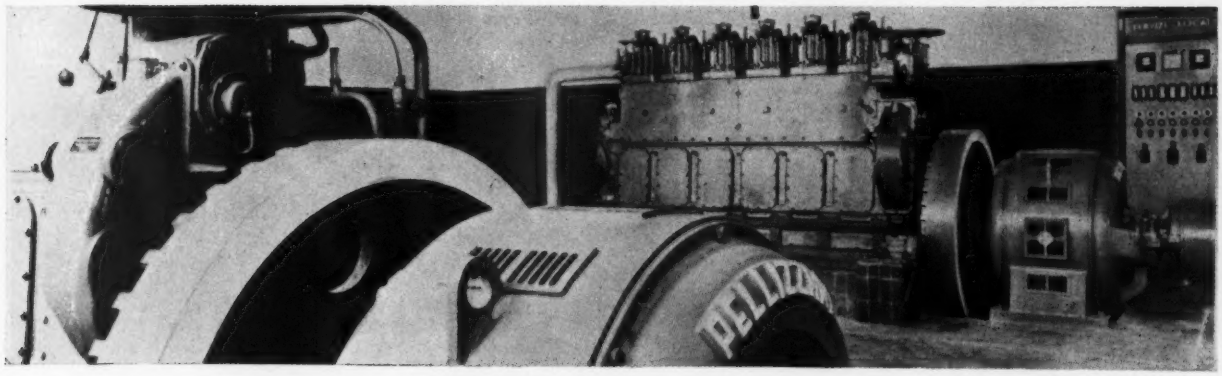

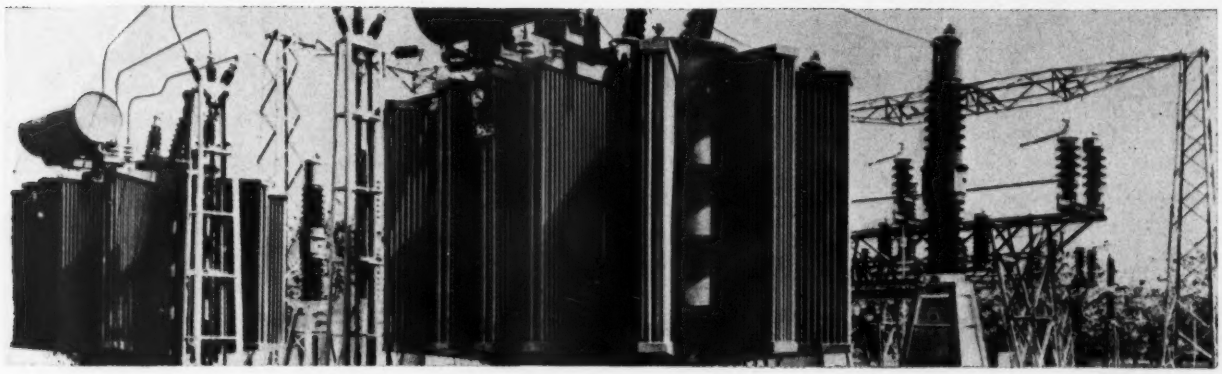

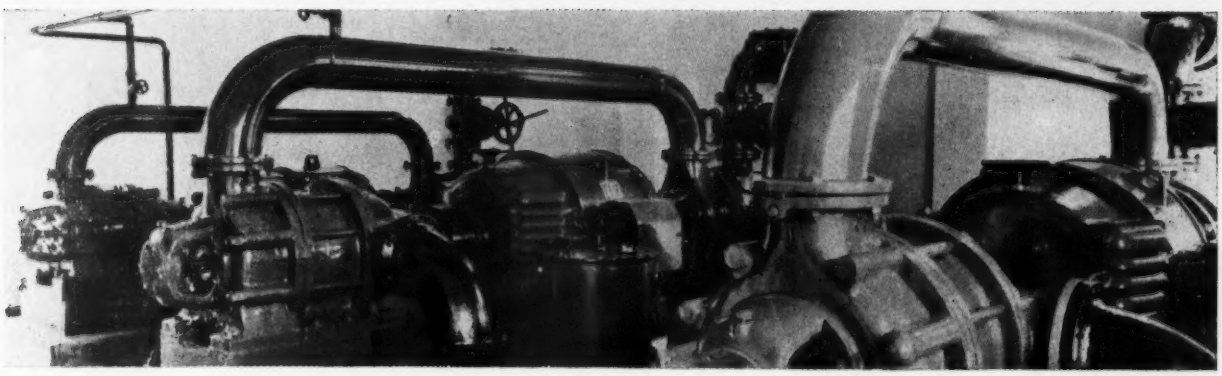

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Harnessing of Resources

The place of the Indus River System in the economy of the undivided Punjab is described and it is shown how the partition made a disastrous difference in the economy of East Punjab. The potentialities of the rivers available for utilisation in East Punjab are then indicated. The emergence of the Bhakra Nangal Project into a practical proposition is described; the size of the Bhakra Nangal Project and its comparison with other Indian and Foreign Projects is analysed. Reference to the controversy of the Nangal Project in the Bhakra-Nangal Scheme is made, and the advantages of such a combination is discussed. The difficulties of construction in its various phases are also referred to. The issue of the utilisation of power generated by the Bhakra Nangal Project has been final taken up.

With the paritition of Punjab, the water resources of the Indus basin have largely remained with West Punjab, who have 80% of the flow due to the major rivers Chenab and Indus. The canal system of the West Punjab is more extensive and modern. The benefits of colonization of crown lands in the Lyallpur, Montgomery and Sargodha districts brought colossal wealth to the West Punjab. The development of East Punjab had remained stunted and narrow.

Consequently the people had developed an anæmic complacence with low standards of production and living.

Unrealized dream

The Bhakra Project had remained an unrealized dream for over forty years. The Sutlej river was the chief asset for bringing water to the arid districts of East Punjab and Rajasthan. The integrated development of the region demanded that irrigation and power facilities be increased to the full to enable the realization of adequate food production and power generation. Only with these resources could the people attain the requisite fruit of their labours. There was no doubt that the people were extremely hardworking and of a virile type. Their forefathers had helped develop in lands in the arid regions of West Punjab in the period 1900-1930.

The solution therefore lay only in the raising of production. There were vast areas in the Hissar, Ambala and Karnal districts in the East Punjab, and also large tracts of land in Pepsu and Rajasthan which were thirsting for water. Command could only be had by very long channels. Similarly absorption losses had to be minimised if the excessive reduction of valuable water at the tail reaches in Rajasthan (300 miles from Source) was to be controlled. The Punjab has pioneered in the construction of the world's biggest lined channels exemplified by the Nangal and Bhakra canals. Here depths upto 30 ft. have been catered in a relatively narrow section in order to minimise cost. Encouraged by the achievement previously attained in the joint Punjab, the Punjab Engneers embarked on the bold programme of constructing the Nangal Canal in the exceedingly difficult reach on the foothills of the Shiwalik range. The result is now acknowledged all the world over as a signal success. Eminent consultants who inspected the works during the course of construction testified to its unique boldness and success.

More production only solution

So far India has struggled to distribute poverty only. There is not enough to go round in the country and all the efforts made so far resulted in bickering amongst the several sections of the people who claim their shares. This is inseparable from the economy of the underdeveloped countries and there never can be any solution unless production is raised to adequate level so as to promote the minimum requisite quota required for the various sections of the community. This has been recognised since long in the Western countries and they have already raised their levels of production so that enough nutrition is available for the entire population and they have also the fullest possible employment. India, unfortunately, has lagged in this race due to historical causes.

Nature has been bountiful

When we look at the map of India and study the reserve of natural wealth available to this country in the shape of mountain, land and rivers, we cannot help being struck by the munificence with which nature has blessed this country. This is also corroborated by the fact that civilization got rooted in this land earlier than other parts of the world and flourished to a very high level. The soil of the Indo-gangetic plains is so deep and fertile that even primitive methods of agriculture have always succeeded in raising much harvest of crops. The climate has enough of sun and rain and barring freaks of nature there is certainty of the labours of the agriculturist being rewarded generally speaking. There are however regions in the land which suffer from recurring floods or draughts and solution for these regions has still to be found. Judging from the achievement of developmental effort in the last 4 years, we can say with confidence that the fate of the country will no doubt be changed in a few decades. This is specially beyond doubt because of the new techniques of generation of power which embrace water as well as atomic resources. A little late but not too late for India to

Prime Minister Nehru with other leaders at Bhakra Site

cover up lost ground and make herself abreast of the more fortunate countries

Progress of country retarded in last 200 years

One has to go back to history to know that the progress of development in this country has suffered a great set back in the last two centuries. The ground covered in the Hindu period took India higher than most of the countries in the world. Subsequently due to world causes and world movements, this bright page of history lost its luster and got soiled with violent movements and commotion which reduced the country considerably in its stature. The industrial revolution which was started in West during the 18th century did not at all touch the shores of India and all methods of production through manual labour became gradually unproductive. The wealth of the country thus underwent a great reduction and other Nations who were young in their spirit of enterprise and conquest over-ran the country and subjugated its institutions. Under such conditions the harnessing of resources in the country naturally suffered a set back and poverty descended upon most of the regions where prosperity had been in evidence for centuries. The connection of the British with this country opened a new chapter. In this period exploitation as well as development went on side by side. So far as the imperial purposes of Britain were served, that displayed remarkable enthusiasm and grit in overcoming all difficulties in rder to bring in an era of greater production. Railroads, roads, canals, hospitals, schools etc all received an impetus of memorable contribution. Yet the poverty of the country was not removed in any substantial degree. The emphasis all the time was on serving of British interest first and last. In the process, however, this country also received great advantages particularly of the unification of people through a common language. This laid the foundation for still greater development which weld forth at the very inception of the independence.

U.S.A. has had only 150 years of big development

There can be no better evidence than that furnished by the U.S.A's. upward march on the path of unrivalled progress. It may be said that development work goes up by leaps and bounds on the analogy of chain reaction. The exploitation of nature by man is like a game in which the more one plays the more he can produce. It is no doubt that the U.S.A. had much larger reserve of resources but there were also handicaps of a small proportion and large tracts of land lying undeveloped with a history, climate and soil condition. It can be said without fear of contradiction that the conditions that obtained in the U.S.A. in most of the various phases of its development programme are not much different from those which prevail in India today. This statement presumes that superficial difference in outlook on religion and philosophy is a minor influence in the struggle for development. The major springs for action are economic forces and the strength and shape of the Government of the country. The evidence of the last 4 years points out to the fact that developments vary in standards reached in the past. In fact new record might be set up when so many people labour as a team under wise leadership in a climate that is charged with progressive thoughts of socialistic achievement This picture is reflected in the rate of progress that the country is achieving in the various fields.

Why and Wherefor of Bhakra Nangal

In the upsurge of development schemes taken up by India since it became an independent Republic, Bhakra Nangal has taken the role of India's premier project, now well on its way to completion. This undertaking has its moorings in the history of the

region dating back to the opening years of the twentieth century. Its completion and potentialities will surely be an outstanding feature for many a decade. The fruition of this development is going to transform the land as well as the people of the region because of the added wealth of food and employment that will follow in the wake of irigation benefits for 10 million acres of land and electric power to the tune of 400,000 k.W.

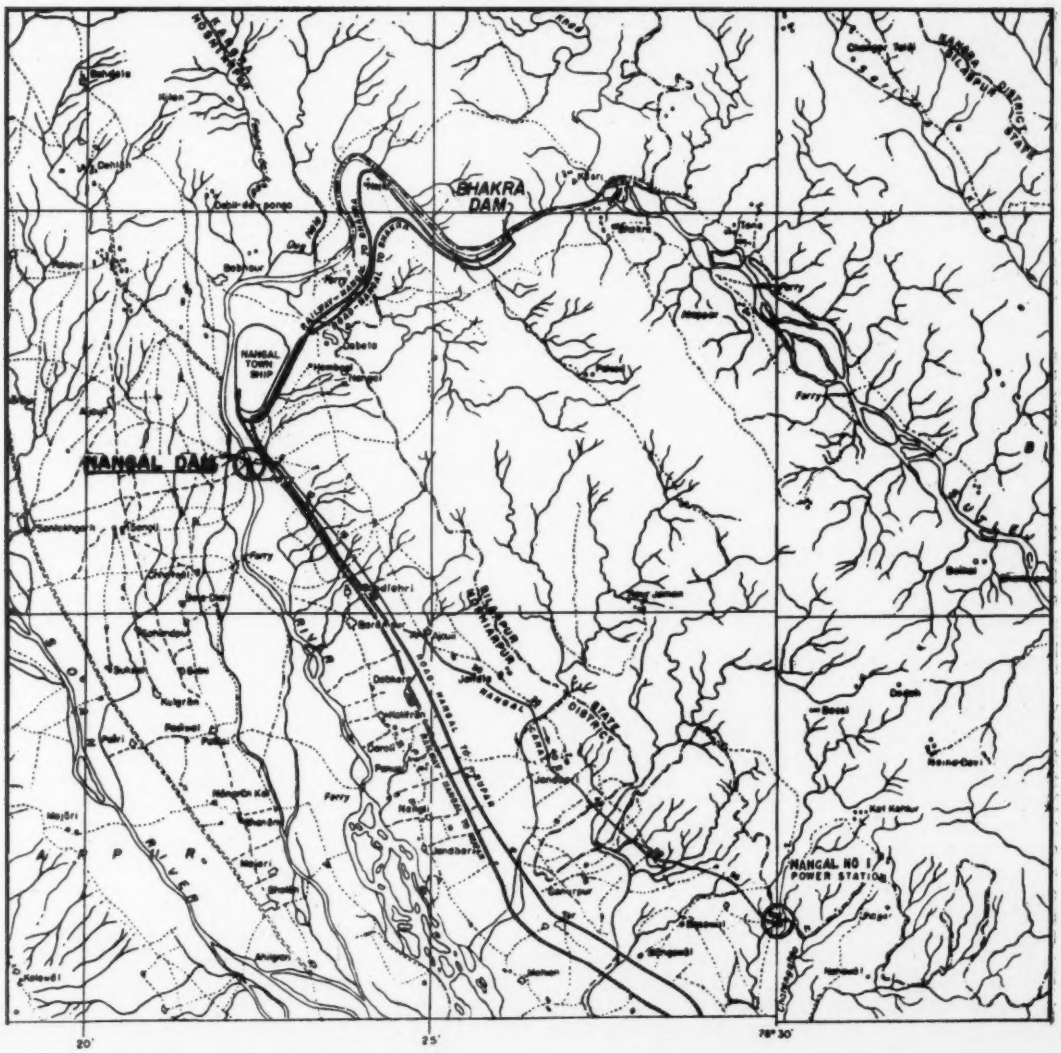
India's biggest

Against the 176 crores (1955 estimate) cost of this project, the D.V.C. and Hirakud are about 100 crores each. The special advantages possessed by the Bhakra Nangal Project are the nature and climate of the region and the traditions and fibre of the inhabitants. The forefathers of the present peasant class migrated some 80 years ago to West Punjab in order to develop the virgin arid lands which were provided with irrigation benefits by the lower Chenab Canal (1890) and the Triple Canal system (1910). These canals created plentiful harvests in wheat, cotton and rice and led to the birth of towns, like Lyallpur, Sargodha and Montgomery, which were rightly styled "the granary of India". After the partition of the country most of the peasantry who migrated from the West Punjab have a martyr-like yearning to recreate within their own lifetimes the prosperity of which they have been cruelly deprived of. Bhakra Nangal gives them the field and the resources from which they can rebuild and resettle themselves. In fact the incentive is on a much bigger scale because of the added opportunity for industrial development which was absent in the British regime.

Boulder, Shasta, Grand Coulee

Amongst the world's high dam projects, the Boulder and the Grand Coulee dams in U.S.A. hold the foremost position in respect of height and mass. They are classical examples in this form of development and will still remain unrivalled for a long time to come. The Bhakra Dam comes in as a close third in

Map showing site of the Bhakra and Nangal Dam and the Nangal Channel



Model of the Dam

respect of size. Its real stature is, however, much bigger on account of the difficulties of design and construction. The foundations are more complicated due to the nature of the strata and the construction is rendered more difficult due to rock excavation. These two factors coupled with the lack of machanization facilities both in equipment and personnel, make Bhakra Dam a more difficult job than either Boulder or Grand Coulee. In some of its features including foundations, spillway and river outlets, Bhakra Dam resembles the Shasta Dam, (U.S.A.) although its problems cover a more difficult range. The fullest advantage has, however, been taken from all these prototypes both in design and construction planning.

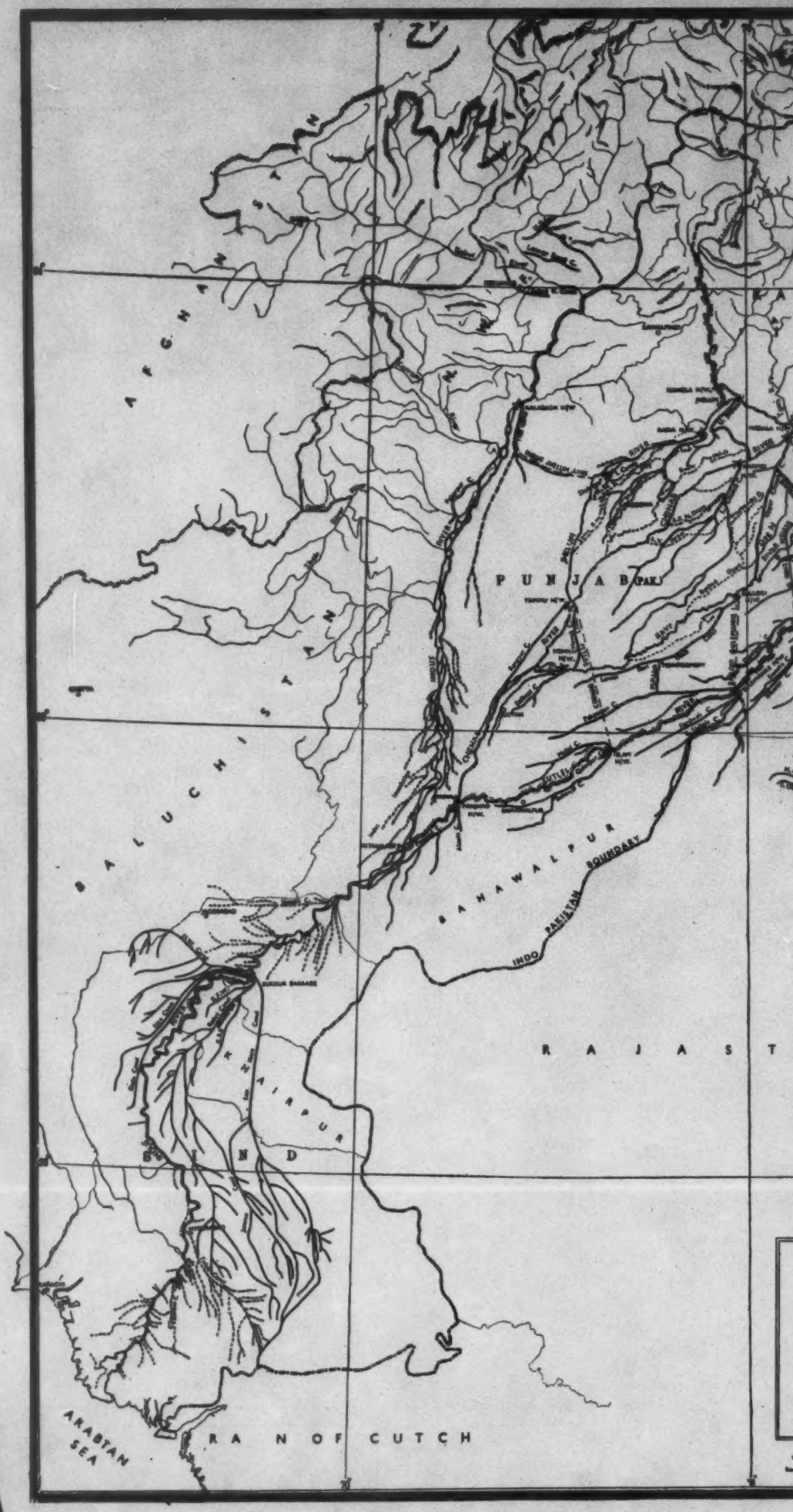
History, Bilaspur

The history of Bhakra Dam is intimately linked with the Bilaspur State—not only in the matter of the physical location of the reservoir which will submerge some 60 sq. miles in the State, but also the fact that great political changes have taken place in this region. For many decades the Bhakra Project was not started because the ruler of Bilaspur could not be persuaded to accept the terms of compensation for the submergence of his palace. The inhabitants living in the reservoir area who will be ousted from their inherited lands, were also unable to make up their minds due to the nebulous alternatives which were presented to them. With the achievement of independence from British rule, and with the merger of most of the Indian States within the administrative set-up of a united India, the problem was taken out of the haze of uncertainty and put on a firm footing. The Rajah of Bilaspur rose equal to the occasion and gave proof of his patriotism by withdrawing his opposition. Similarly the people affected, felt secure in their confidence that the National Government will pay sympathetic attention to their just claim with generous understanding. The future of the Bilaspur State will no doubt be full of promise because of the impact of tourist traffic that will be drawn to this largest inland lake which will be created by the impounding of waters upstream of the 680 ft. high dam. New avenues of trade and employment will be opened by the advent of electrical power which will follow in the wake of added wealth earned by the Bilaspur workers due to their employment on the various operations necessary for the building of this gigantic dam.

Comparison with Ganges and Jhelum

The name of Colonel Cautley will ever be remembered in the history of India's river valley development projects for the great engineering feat that he performed (1854) in the planning and construction of the Upper Ganga Canal. Similarly the Upper Jhelum Canal construction in the Punjab in 1912, was another classic example of canal engineering, almost equal to the Ganga canal in the boldness of its cuttings, embankments and cross-drainage works. The execution of both these projects utilized manual labour and the simple types of machines, largely of the steam driven locomotive and tractive type. The Nangal Canal is not only a much larger channel (12,500 cusecs) as compared with Upper Ganga (8,000 cusecs) and Upper Jhelum (7,000 cusecs), but it involves modern techniques of construction which are in advance of even U.S.A. and Europe. This canal which will meet the most exacting demands of irrigation and hydro-electric generation is a 40 mile long museum of engineering skill in design and construction. A lined channel with depths ranging from 80′ to 28′, it negotiates some very difficult country cut-off with torrents at 60 odd places. The range of discharges varies from 200 cusecs to 150,000 cusecs (Sirsa Nadi at mile 29). The embankments in the various ravines range between 20′ to 80′. The maximum cutting is as much as 120′. Besides all these difficult features this canal is harnessed at two places (mile 14, and mile 18) by two medium head (100′ drop) powerplants which are amongst the largest of their kind in Asia.

A fuller description of the project is given elsewhere.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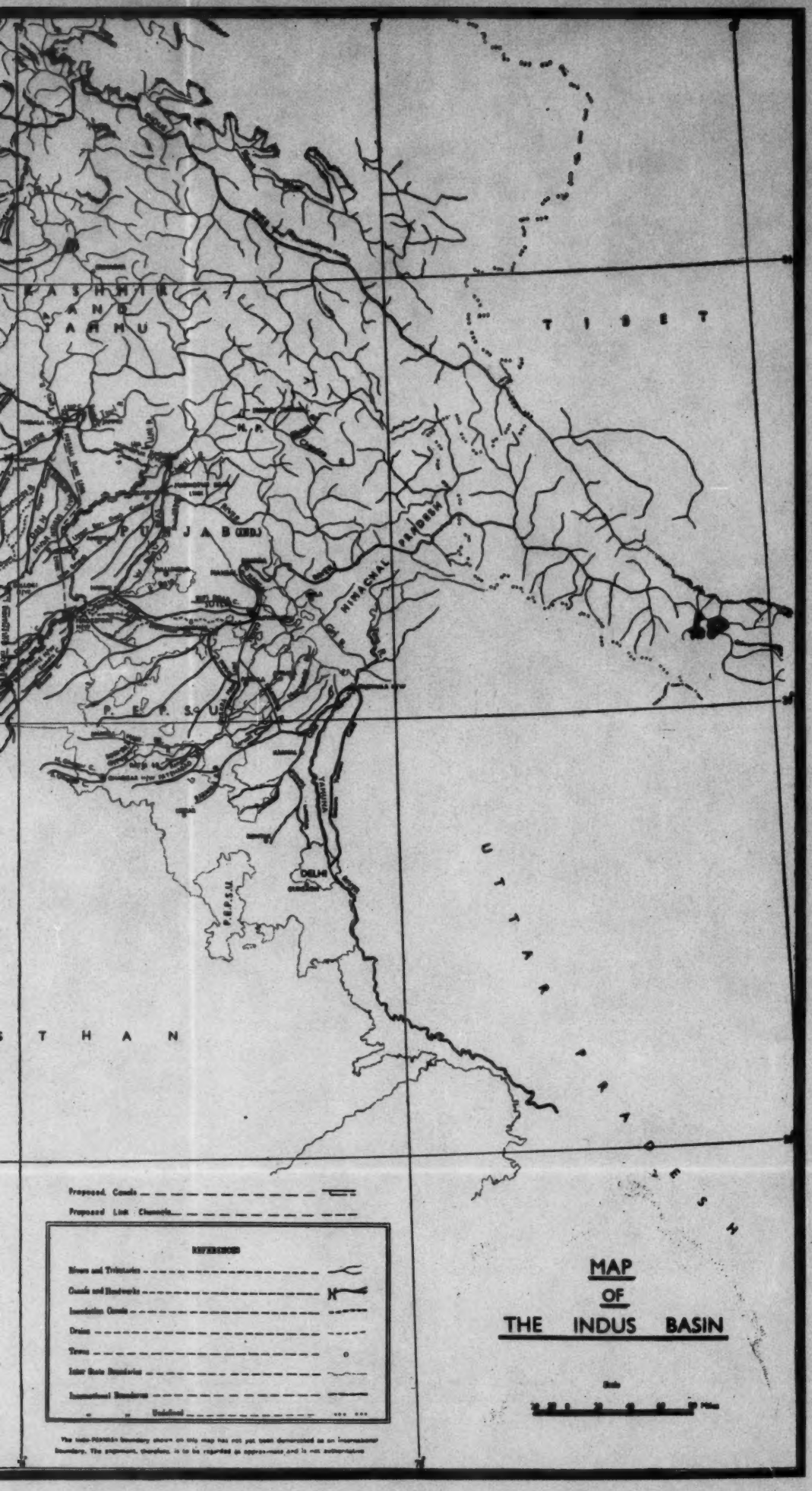


Why Nangal

The fact that about 100,000 K.W. of power will be added to the resources of the Punjab, Pepsu, Delhi, Rajasthan, regions by the end of 1955, yields ample testimony that Nangal development was its own justification. Power from Bhakra Dam is still in the distance. The installation of the first unit of Bhakra Dam will take at least four years more, if not longer. The power famine first made itself felt in the joint Punjab during the II World War when a stage was reached that the giving of a connection for even a 40 W light in public hospitals and schools became impossible. The private consumer was nowhere in the picture and months and years had to be spent in suspense at the door of the electricity authorities before the detailed applications ever got a chance. Such a situation was most discouraging for the expansion of the industries or even for the operation of necessary amentities, e.g. pumping plants, lighting and fans. Nangal Project was an answer to this situation.

Some controversy arose at the time of sanction of the Nangal Project on the grounds that Nangal was unnecessary for power generation when Bhakra Dam had all the potentialities required. The argument advanced against this view was that on a realistic assessment, the completion of the Bhakra Dam must take 10 to 12 years on account of the magnitude and complexity of the job. The completion of the Nangal Canal and powerhouses could be envisaged with certainty because the technical know-how and the construction equipment were readily available. The same was not true of the Bhakra Dam which was a job with a far greater element of complexity. Again it had a much bigger quantity schedule in excavation and concreting. The technique of building a high dam was relatively new to India and quite a substantial contribution would have to be sought from foreign sources both in men and machinery. If, therefore, without any set-back of Bhakra Dam work, the country could also get electric power 5 years in advance of the Bhakra Powerplant, the idea was well worth accomplishing.

For the above reasons, the decision was taken in favour of the prior completion of the Nangal Project with a concurrent schedule for the Bhakra Dam Project. The construction of the Bhakra canals was also simultaneously undertaken. The Nangal Canal would act as a feeder channel for the Bhakra Canals. This function of the Nangal canal was a unique advantage over the previous projects in which the Bhakra Canals were to be fed from Rupar headworks by enlargement of the Sirhind Canal in the 12 miles of its head reach. This work had its own difficulties and it would have subjected even the Sirhind Canal supplies to interruptions during the currency of the work, and jeopardised the economy of the region. This factor also influenced the decision in favour of the independent Nangal Canal rather than the combined Bhakra-cum-Sirhind canal.

Even though the justification for the Nangal Project was irrefutable on the grounds of earlier supply of power, it must be appreciated that the degree of firmness of power from a canal development cannot at all compare with the power to be obtained from a high dam, like the Bhakra. In the history of lined or unlined canals, the interruption of supplies due to river floods, headworks repairs, bank breaches, silting problems etc. etc. is a well recognized feature. Hence, it would not be realistic if any one maintained that the Supplies of power from Nangal power houses were 100% firm. The necessity of closures on the Nangal canal cannot be ruled out even though such closures will be cut to the very minimum. Thus, the Nangal Project cannot stand on its own feet under any circumstances. Its full potentiality can be developed and utilized only when it is firmed up by the Bhakra Power Plant.

Why Bhakra

That brings us to the conclusion that the Bhakra powerplant must be constructed in all speed to reduce the risk of operating Nangal without Bhakra. By constructing Nangal powerhouses we have gained some valuable time in the earlier creation of a sizeable source of power. Also, Nangal will directly help the construction of the Bhakra Dam with cheap and reliable consumption of power during the next 5 years upto the completion and comissioning of the Bhakra Power plant.

The creation of the reservoir at Bhakra will firm up the supplies in Nangal canal during the winter months when the natural flow of the river is at the lowest ebb. The firm power potential of the Nangal Canal will be considerably raised after the Bhakra Dam storage is available.

Nangal versus Bhakra

The relative merits of Nangal and Bhakra Dam development do not permit of a strict comparison. These projects are like the roots and the trunk of a tree and are both necessary for full fruition. A lot of the controversy that arose on the issue of Nangal versus Bhakra could have been avoided if the problem was examined in a true perspective. Now that the proposal for a big fertilizer plant at Nangal has been initiated by the Government, there is hardly any doubt that the full capacity of Nangal and Bhakra Left Powerplant will be substantially utilized without any wasteful time lag.

Nangal with Bhakra

The above analysis will indicate that the Bhakra Dam Project has been enriched by the inclusion of the Nangal Project. In fact the whole development is now divided into stages which will expand into an integrated picture in a scientific manner. These stages are specifically listed below :

1. Khariff irrigation furnished from new channels of the Bhakra Canal system fed by other than Bhakra Canals (Sidhwan Canal from the Sirhind : Barwala system from Western Yamuna Canal 1950).

2. Kharif supplies for the Bhakra Canal system from the flood flows of the Sutlej River (1954).

3. Power supply from the Ganguwal Powerplant on Nangal Canal (1955).

4. Added power supply from the Kotla Powerhouse (1956) Nangal Canal.

5. Firming up of some of the Kharif irrigation system with the pre-completion storage in the Bhakra Lake (1958).

6. Generation of power from Bhakra powerplant first unit (1959).

7. Additional Bhakra units (1959-60).

8. Completion of dam for full storage (1960).

The above developments envisage the full utilization of the benefits of irrigatin (10 million acres) and power (400,000 k.W. firm, 300,000 kW secondary).

It will be seen that the earning of revenues started in 1951-52 and this would progressively increase in the interim period of the completion of the Project to its final stages. This is a unique feature of the Bhakra Nangal Project and will greatly help its eventual success.

The same pattern of development is not possible at other projects in the country where demand for irrigation is not so keen and the tradition of the people is not so well fitted for pioneering endeavour in the field of land reclamation, cultivation and industry.

Exceedingly difficult

In achieving the targets of the Bhakra Nangal programmes, several difficulties had to be faced and solved. Those responsible for the project faced a heavy challenge in initiative, resource and improvisation for surmounting the hurdles. Some of the items in which outstanding success was achieved deserve to be highlighted :

(*a*) Construction based primarily on modern machinery. Examples are earthmoving equipment, tractors, scrapers, draglines, shovels etc.

(*b*) Mechanization of transport, with large units, e.g. 14 yds Euclid trucks, Dumpers and heavy duty vehicles.

(*c*) New construction techniques for the construction of tunnels (50′ diameter) and related works.

(*d*) A railway-cum-road bridge constructed on the Sutlej River in a period of 7 months.

(*e*) Modern methods for the manufacture of concrete according to the latest findings of research.

(*f*) labour force over 1½ lakhs strong employed at the peak stage of construction.

(*g*) Large scale requirement of foreign technicians to secure on-the-spot consultations for arriving at prompt decisions.

(*h*) A good deal of the permanent equipment e.g. gates and gearing, scroll cases, hoists, penstocks manufactured within the country. This was undertaken and finished to a high standard of performance.

(*i*) Suitable workships set up or expanded in order to cope with the heavy programme of maintenance and repairs of equipment.

(*j*) Large forces of personnel trained in the various skills of operating, servicing and overhauling of equipment.

Social consequences of the Bhakra Nangal Project

For a real rise of standards in the living of the people, it is only the stepping up of the production that can provide an effective remedy. Any talk of better living by a mere levelling down process and redistribution of wealth and resources by taking it away from the "haves" and giving it to the "have-nots" cannot lead to a satisfactory solution. It is in this context that the Bhakra Nangal Project deserves special recognition.

A visit to the project will indicate that on the job itself there is a refreshingly democratic equality of status for all workers. In fact the white tin helmets of the same type are borne from the lowest paid labourer to the highest paid official. This is a step in the direction of raising the dignity of labour. At Bhakra, there is a practice now being followed for picking out the best worker of the month, whether he be a Euclid driver, a shovel operator or a Crane mechanic. When the best worker finds himself publicly eulogised, it spreads a wave of enthusiasm and satisfaction amongst the other good workers as they hope one day to be singled out for the distinction.

The same sort of process based on the recognition of dignity of worker is to be found inside the design and drawing offices also. Here all the design and drafting personnel including officers sit in the same room and have complete access to each other. The Officers are not segregating themselves into separate rooms and there is a unique feeling of fellowship which has seldom been enjoyed in the Indian offices during British days. The Officers are primary workers themselves and their designs and drawings are personal outturn. This ensures a high quality of work and at the same time adds to the quantity of output because the routine of marking problems to lower ranks is not followed. During the process of deliberations and study, the engineers evolve better and better ideas for incorporation in their finish work. The position is very much comparable to that of an artist who is producing his work and everything is thought into expression.

All over the project, where departmental work has been done, the working forces have been provided with amenities like chlorinated iced water available on the job all the time. This factor could only be secured by having a number of water transport vehicles with bulk ice blocks supplied from a refrigerating plant. The factor of reliable water being available has ensured good health and better spirits for continued application to an arduous job under all conditions of sun and weather.

Apart from introduction of facilities and raising of standards of the workers on the job itself, the countryside where work is going on has seen the advent of electricity, whether the work was situated in the hilly gorges or the out of way torrent beds or alongside villages, which are far removed from civilization. The execution of the works of the Project has brought a new light in these regions due to the penetration of the construction machinery and all the other arrangements that accompany it. Not only has this brought more employment but it has enabled coming together of divergent sections of the people who did not otherwise come across each other in their daily routine.

(*Continued on page* 13)

Agency of Construction

The Bhakra Dam being not of a type usually planned in India, the problem of its construction arose. The full story of how it was taken up departmentally in spite of the lack of experience of Indian engineers is given here: how American and French contracting firms tried to undertake the project and what were the difficulties that were met in negotiating. The advantage of departmental construction not only in the matter of the project itself but also for the country as a whole has been explained.

The Bhakra Dam construction remained a subject of controversy for almost six or seven years. One school of thought considered that the job was entirely beyond the experience of the department and it would be a great risk if the work was started without the help of an experienced foreign firm. Accordingly a recommendation was made that Messrs. Morrison Knudsen of U.S.A. should be approached for taking up the contract.

There are two ways in which such a job is usually contracted. The firm could tender prices for unit rates for various items like rock excavation, concreting, steel work etc. or they could quote the cost price plus their fee for each item. The second alternative had the disadvantage that there would be no control over the ceiling for each item. The inefficiency or the expensiveness of the contractor would be visited on the owner, who would not have any effective control over the various operations of the job. Such an arrangement became popular for certain works which in the Second World War, were contracted to big construction companies by the U.S. Government. Messrs. Morrison Knudsen offered an incentive clause in this arrangement, by agreeing to abide by the target estimate, which was framed jointly by the firms representatives and the government officials. Any savings from this target estimate were to be shared equally by the firm and the department. The snag in this would be that the target estimate would be very high if the firm were to cover all unknown contingencies of working in a foreign land, of which the rates and regulations were materially different from their country. A further complication would be the other working conditions—particularly the fact that materials like cement, steel and spare parts could not be supplied to the firm in accordance with the guaranteed schedule. Thus stipulation regarding adherence to the target estimate would have had to be modified, sooner than later.

Special Features of the Bhakra Dam Work

The fact that over 50% of the work on Bhakra Nangal project comprised items like earthen and lined channels had an important bearing on the agency of execution. For the construction of the Nangal Hydel Canal, the departmental organization was quite experienced and competent. The officers who had worked on the Haveli and Thal Projects of West Punjab were still available. They had been pioneers in this work ten years ago and the greater magnitude and complexity of the Nangal Canal did not present any insurmountable difficulties as far as the technical aspect was concerned. Thus a huge organization grew up and was in shape to tackle the colossal work of excavation, embankments and lining with concrete or brick masonry. This work was also largely mechanized so far as transportation, and concrete manufacture was concerned. It became quite obvious that the balance of advantages would be in favour of departmental construction with a common pool of construction equipment. Accordingly the nucleus for Nangal Dam and Nangal Hydel Canal sprang up at Nangal Township where a large workshop grew up from a small beginning. The equipment from army disposals was drawn upon continuously till many a useful machine was created by overhaul, improvisation and rebuilding. It was through this process of selection and adaptation that the biggest project of the country has been brought to the present stature.

Know-how and Training

One important consideration which applied to the case of Bhakra Dam proper was the desirability of obtaining adequate know-how within the country for future projects. If the work of construction was entrusted to a foreign contracting firm, they would obviously be not willing to part with the "trade secrets" and they would have allowed Indian engineers to stand by in the role of observers. In this role no opportunity would have been available to Indian engineers to exercise their full initiative or take responsibility for any vital decisions. It is a matter of common observation that jobs completed by foreign companies make us more and more dependent on them for subsequent jobs. A case in point is that of Mandi Hydro-electric Project where most of the civil construction and erection of electrical plant was done on contract by foreign company. The Electricity Branch of the Punjab State were mostly observers and facilities for training of their personnel could not be had.

It is said of Japan that they import only two machines of a new type. One machine is stripped and its various components are then manufactured within the country by a combine of manufacturers. The unit is then assembled and tested in comparison to the imported unit which was not dismantled. In this

way the country has progressed at an astounding pace. This principle has a great lesson for India in the present stage of her development. What applies to machinery also applies to new jobs of civil construction and this consideration deserves utmost attention.

Small Jobs

The history of Public Works Department of various States is full of numerous instances in which undertakings of a most difficult nature have been successfully tackled, whether they related to river works, unwatering foundation or large masses of concrete or masonry. The nature of such jobs was relatively simple as compared with high dam projects. The barrages and weirs constructed in India required organizational and technical skill but the scale of it was rather small. The cost of some of our biggest barrages is only 1/10th to 1/6th of Bhakra Dam. Apart from this, the nature of the job due to restriction of space and difficulty of access makes it specially complicated. The successful construction of the dam within the limit of economical feasibility needed completely different process in excavation, transportation of material and concreting. As such the previous know-how available within the country was not adequate to take care of this job. In the case of the Bhakra Dam the Engineers admitted this fact in a realistic way and this factor is responsible for the ultimate shape of the construction agency.

Mechanisation

It was conceded at an early stage that the Bhakra Dam job depended entirely on mechanisation for its successful completion. Now a vast range of machines has been used on similar operations under various conditions. There are no thumb rules or hard and fast lines on each construction and plant lay-out lines on which Bhakra Dam could be finally determined. There is great scope for alternatives as to methods and plant in almost every operation. Yet there is something called an over-all optimum advantage in the co-ordinated picture. For this purpose, it became essential to rely upon the consultation and experience of well known experts, whether they may be organizations, like the T.V.A., Bureau of Reclamation and Army Crops of Engineers (U.SA) or selected individuals, who have spent years of their life on the design and construction of high dams. It was only through such high level concentration that pit-falls could be avoidedand expensive mistakes could be eliminated from the basic plant. In the case of the Bhakra Dam the difference in cost between two feasible alternatives could be as much as 100%. It is only experience and some sort of an intuition for construction techniques, which could lay down the main frame-work within which further finalization of the plan could be carried out.

Hiring of Experts

In view of the above analysis it became apparent that the best insurance for building the Dom in a sound manner and least time would be to hire some experts and to place them by the side of the Indian management (engineers of administrative and executive ranks) so that the big problem could be tackled under the continuous advice of foreign experts. The contracts of foreign experts were drawn up for a limited period in order to keep in people with the phased programme of construction. In every case, Indian Engineers were allocated duties concurrently with the experts for various operations so that experience and know-how are equally transmitted and picked up by the Indian engineers. The actual working of three years have demonstrated that this method was of great success as it succeeded in the objective of Indian engineers picking up the necessary know-how and being able to do the job of foreign experts in due course of time.

Indian Firms not yet capable

The occasion brings one conclusion very forcibly. The Indian Contracting Firms are not as yet capable of handling jobs like the Bhakra Dam. There is no question that their efficiency and capacity have already been proved in jobs like the Vaitarana dam, but there is a great difference between Bhakra Dam and any other dam construction in the country. The number of intangibles and the complexity of the Bhakra Dam problems surpass all other dams and it is just as well that the Government of India approved the recommendations of the Punjab Government for executing the Bhakra Dam job departmentally by the hiring of expert personnel from abroad and also manning the organization with an adequate strength of selected Indian engineers who would bear the main brunt of the operations. By this process not only is the successful and sound completion of the Bhakra Dam ensured but sufficient know-how will become available in the country for starting other projects of the Second Five Year plan which are of less complicated nature.

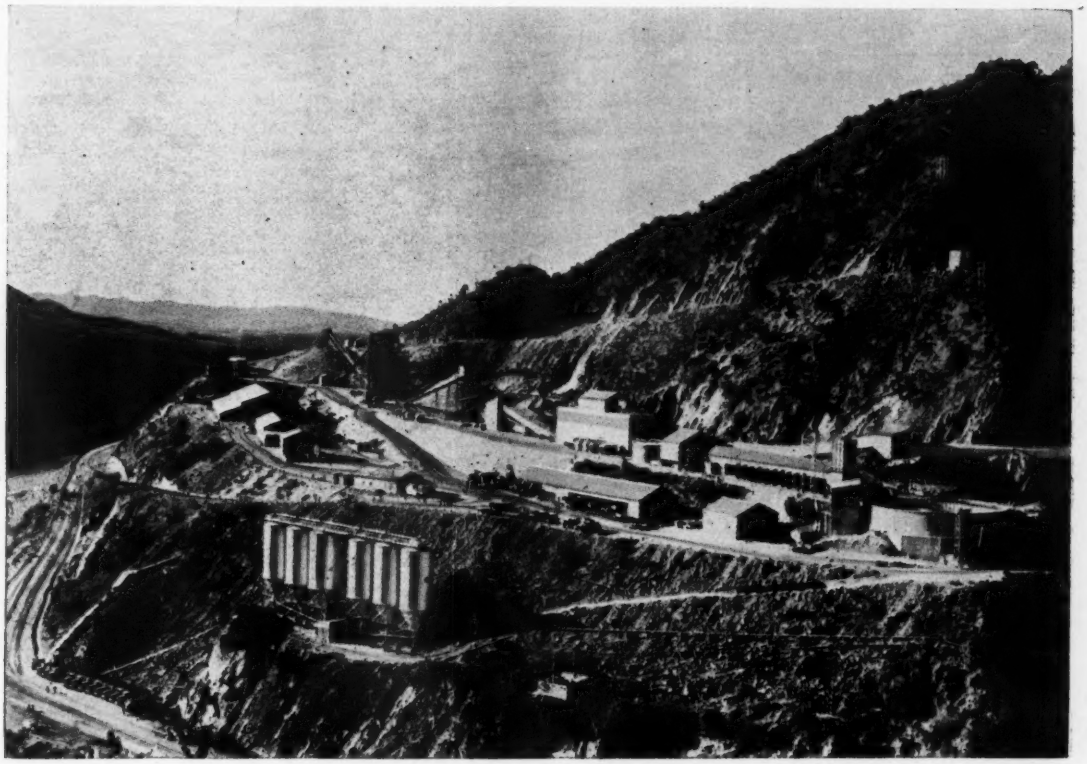
Part played by eminent Indian Engineers

Eminent engineers notably Shri A. N. Khosla and Shri Kanwar Sain brought home to the State Government and Government of India that no further postponement of this project should be allowed. With the vast design and construction experience gained in this country and through their visits abroad they had all the imagination and courage for recommending this project in a firm and unequivocal manner. They were ready to undertake this work either departmentally or on the merits of a suitable firm volunteering to do the job. Their preference was however always for departmental construction as it was considered a more flexible method and it was anticipated that large amount of time and money would be saved if the hands of the authorities were left free in the matter of evolving a suitable design on the basis of exploration and other site conditions.

Although a such chance was not given at any stage for foreign firms to submit tenders for the entire Bhakra Dam job, some American and French Firms did try their best to obtain an award in their favour for starting the project on a cost plus basis.

Private Contractors versus Departmental Agencies

A great deal of experimentation has been done recently regarding the responsibility for the care and operation of construction equipment which is employed on a project. In most of the cases, there has been no private contractor of sufficient financial resources who could undertake to provide the machines required for carrying out a big job. The initial capital investment has always to be of Government. If a job is being executed on a private contract the contractor



A panoramic view of the Plant Layout

agrees to pay for the use of the machines at a per hour basis. Even this arrangement is full of risk, because sometimes the contractor likes to work the machines irrespective of their intrinsic condition simply because he can make more money by not stopping the machines at that particular time. The other alternative is that the machines be maintained under the departmental organization and the contractor's rate be made exclusive of the overall cost of the machines. This arrangement is by no means clear-cut in its financial implication because it leaves too many loopholes in favour of the Government Staff to run the machines as they like. As such the contractor's work can be adversely affected. However the contractor still prefers this arrangement because it enables him to steer clear of the initial heavy investment. On account of many considerations, departmental execution of work has been adopted for the Bhakra Dam proper. On the rest of Bhakra Nangal Project, including Power houses on the Nangal Canal, the machines were run at the direct care of the department, with the contractor receiving payments only for the manual labour cost of work order items which excluded the capital and working cost of machinery.

The Punjab has now enough experience in this line to be able to make such arrangements in different situations. However, it must be admitted that there is nothing to beat the codal contract system with the machines also being procured and operated by the Contractor. The over-all unit rate can then be all-inclusive. But for this unified responsibility rates are at present very high. The rates can be cut down only if the official agency in a department undertakes to plan, organize and supervise the execution of works. But even in this system, there are some snags due to the lack of sufficient authority with the engineers on the spot. These handicaps are dealt with elsewhere in greater detail.

Contractual work

Bhakra Dam construction can well be regarded as the touch-stone where the issue of the agency of construction was thrashed out in all its aspects. The Punjab Irrigation department was nearly a century old and considerable experience had no doubt been gained by the Engineers from the construction of its sizable canal projects dating as far back as 1850, when the Upper Bari Doab Canal was constructed under the British Engineers after the last Sikh War in order to settle the unruly element of the newly conquered province. Thereafter the Punjab had had its famous canal systems—The Western Yamuna irrigating Karnal, Delhi, Rohtak and Hissar; the Sirhind Canal irrigating Ludhiana, Ferozepur and Pepsu, and then the triple canal system derived from the interlinking of the Jhelum, Chenab and Ravi rivers. The last pre-partition venture of the Punjab Irrigation department was the Haveli and Thal Projects where for the first time, lined canal systems were constructed with a head discharge of 10,000 cusecs in the Thal Canal.

All the same there was no parallel in the construction of a concrete dam in the entire history of the department. The scale on which mechanization would

be required was also beyond the tallest imagination of the engineers charged with the responsibility of execution. It was therefore apparent that either the work could be accomplished by the engaging of a competent foreign contracting firm or the department had to be expanded a great deal in order to develop competency for the planning, design and construction of the mamoth job. In particular the hurdle of machinery needed for the Project was the biggest, for the crossing of which, prolonged and varied efforts were made for almost six years before it was solved with the present set up of experts engaged from U.S.A., where the department has set up a liaison office run by the Technical attache of the Project who works in close coordination with the India Supply Mission in Washington D.C.

Assured Completion

It was recognized early enough that the Bhakra Dam Project job was quite different from any of the earlier diversion weir or barrage projects. As the costs of materials and labour were mounting, the financial feasibility of the project hinged on economical planning and construction. The assured completion of the dam depended on a co-ordination of a great many factors some of which were quite beyond the experience and jurisdiction of the department and the State Government. Hence the backing and day-to-day support of the Government of India would be required for foreign exchange, import licences and hghest priorities in transport. Besides the timely siupply of steel and cement would also have to be guaranteed. It was only after these pre-requisities were fulfilled that the Project completion could be regarded as a practical possibility. With this background the various alternatives of contractual and departmental work were examined in an atmosphere where controversy put up its head again and again. The issue admitted of more than one solution and history in this case was shaped according to the predilections of the individuals who held key position in the management at various phases.

Unit costs versus cost plus rates

The consensus of opinion ranged between a firm contract on unit price basis for various items, or the departmental construction with the help of foreign experts. The foreign firms (American and French) who studied the project were however disinclined to quote on unit price basis due to the peculiar circumstances of the job—which was not only unprecedented in size but had also a number of special features not found on other projects of equivalent size. Due to these factors, the firms were ready to make a quotation on cost plus basis. Such a contract would have the disadvantage of uncertainty as to cost and quality and the target of time would also be quite fluid as it would be hard to pin down any firm to a rigid schedule, when the department and the Government were themselves not in a position to guarantee their own part of the agreement. In the case of a cost plus contract, there would be no stimulating incentive for the firm except their reputation to do the job soundly, economically and with speed. And as the uncertainties in the various requirements were numerous and serious, no firm of repute and experience could be expected to name a price which could be regarded as reasonable from the point of view of Government. They wanted to keep a high margin up their sleeves to contend with the uncertainty factor. One of the firms agreed to a target estimate—but any excess was to be borne by Government and savings divided half and half between Government and the contractor. This was a plausible incentive clause—but it did not provide any positive guarantee as to the total cost of the job. The result would have been litigation in case of dispute and in all such cases, the benefit of doubt goes to the private contractor rather than the Government. The contractor has greater liberty of action to collect and produce evidence and his lawyers are usually of a higher calibre and experience in this field.

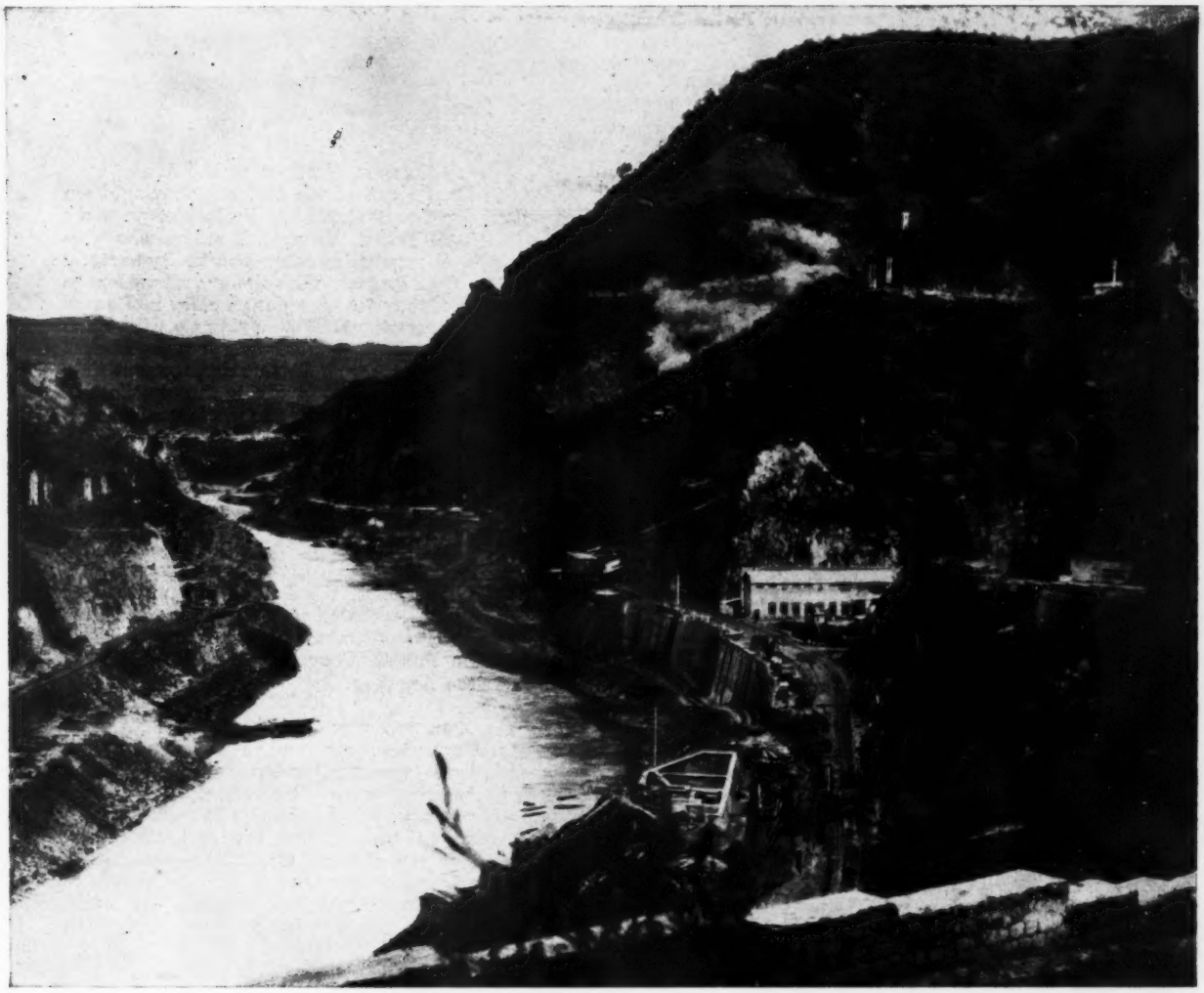
Contractor's Bid bound to be too high other factors

In the above circumstances, unless a contractor was interested in digging his toes into the job with a seemingly low bid (to be eventually increased through claims or escalator clauses), the letting out of the entire work on a codal contract would have required a much higher price to be paid by Government than they were prepared for. There is no doubt that with progress of the job, new features would have been discovered necessitating greater outlay on the part of the contractor due to the caution necessary in the excavation of foundations. Similarly the cost of trenching in claystone and backfilling of concrete would have in all probability exceeded the target estimate which in 1949-50 could only be based on guesswork rather than actual exposures. And as all these matters were absolutely vital for the safety of the dam, no economies in expenditure could be accepted at the cost of soundness or overall stability. Thus it was in the overall interest of the project, that its execution be done departmentally.

Design not finalized

It must be remembered throughout our story of the Bhakra Dam that certain phases of the work did not permit the finalization of the designs right upto the time of concreting. The reason was the unforeseeable nature of the foundations due to the presence of claystone rock which occurred at the upstream heel, middle third and then below the toe of the dam. In the locations the excavation had to be kept down to the minimum, firstly to preserve the side-walls of sandstone to the maximum safe extent and secondly, to reduce the quantity of backfill concrete to the minimum. Due to this peculiar feature the construction designs, drawings and estimates had to be kept flexible. The exposures had to be examined by expert geologists and engineers during the progress of exacavation and drillings, to evolve to most economical safe design.

The other important feature where the designs had to be kept flexible was the powerplant location and extent and programme of construction. An examination of the load survey carried out in 1952 and then in 1953 indicated that there was poor prospect of the generation from Bhakra Dam being absorbed upto sometime after 1964. As such the locking up of big investment on the Bhakra Power Plant units was discountenanced by the Government and the Planning Commission. Various alternatives were then considered to execute only such part of the work as must be done concurrently with the dam so as not to adversely affect the safety of the structure. The excavation and concreting of the foundations for the left power plant came under the category as also the excavation and concreting of the penstock tunnels



A view of the Bhakra Gorge in October 1953

including steel liners. These factors necessitated that the final design be kept flexible so far as the sequence and extent of construction was concerned. Added to the difficult nature of the job this aspect made departmental construction inevitable. It is well known that design changes subsequent to the award of a contract always give occasion to the contractor to raise his price and it is difficult to controvert him.

Advantages of departmental construction

The one advantage of departmental method of construction of Bhakra Dam has been the continuity of the work. Considering that many of the decisions regarding the design of the dam could not have been finalized in advance, it was decided advantage that maximum flexibility had been retained. If the job had been let out on contract, the unavoidable delays and hold-ups would have led to irrefutable claims and compensations that the contractor would have demanded.

Flexibility and Design changes

The treatment of foundations and the gradually crystallizing decisions on powerplant, have fitted in appropriately with departmental working. Not only have they permitted dove-tailing into the construction schedule, but sufficient time and thought have been given to the evolving of solutions reached in agreement with several consultants of renowned experience. As a result of the unhustled deliberations, many favourable elements have been injected into the design leading to improvements in soundness and economy.

Cheapest in the long run

Judged in this context, departmental management is bound to prove cheapest in the long run. It unifies the interest of the Project and the workers, who are consequently able to put in their best in accordance with the contingencies of the situation. There is no reason for making any economies which may be harmful to the work. The materials used are of the best quality and in the right proportions. Any savings made accrue to the State, and increase the financial productivity of the Project. The workers thus become real partners in the enterprise. The example of un-

remitting endeavour set up by the higher officials becomes a model and a motto all along the line organization and every worker contributes his best and fullest to the successful and timely accomplishment of the job. Assuming that the management selected by Government for departmental working is efficient and honest, the rates of various items of work have been seen to bear a favourable comparison with the rates paid to contractors, where the work is let out on contract.

Training Value and Capitalisation of Experience

The biggest value of departmental construction lies in the unique opportunity that it affords for the training of personnelin the various trades. When the job is given to a contractor, the initiative of "how it should be done" passes on to him and his men. Whatever staff is kept on behalf of Government either for inspection or for measurement of works ceases to have interest in direction or planning. They are reduced gradually to the role of observers or by-standers.

No contractor can really afford to train any men unless they are working on his payroll and their inefficiency directly cuts away his profits. Training of personnel costs money and it is only employers like the State that can afford to let its expensive machines be handled by novices and apprentices under supervision. As personnel forms a major bottleneck in the implementation of the country's five year plans, it is of the highest importance that some of the major projects of the country are executed in the public sector so as to yeild a big crop of trained workers who can be switched on from one job to another similar job thus enabling fullest use of the experience acquired by them under the aegis of Government.

Quickest, depending on Leadership

For a project like the Bhakra Dam it may be stated for a good reason, that departmental execution is, in the overall picture, perhaps the quickest and the most economical way of executing the job. This is the prospect notwithstanding the fact that there are several handicaps and bottle-necks which would have not existed if the job were under contractual management. Much greater vigilence is however called for on the part of the Government engineers who have been selected to shoulder the responsibility.

Big Contracting Firms

From the very start Bhakra Nangal Project had attracted big firms to get interested in the job. For a long time the picture was rather ill-defined because the Government authorities themselves were rather hazy about the cost and the programme. It was not fully realized that the starting of the Project meant the undertaking of a very heavy responsibility and the investment necessary for the completion of the job have to be guaranteed at all stages. Again a good deal of the investment would be needed in foreign currency of the dollar area because most of the construction machinery would have to be imported from the United States of America. Prior to independence, the British Chief Engineers were unable to stretch themselves to the required stature either on account of apathy or hesitation to tackle a job of such enormous proportions. And not having done any similar projects within their experience, they hesitated to advise the Punjab Government in its favour. As has been mentioned elsewhere, the demand for electric power was advocated by the British engineers to be met by the new Nangal Project, as they felt that Bhakra Dam was a dream project never to be translated into actual practice.

Morrison Knudson of U.S.A.

Due to Dr. Savage of the U.S.B.R. having been consulted for the Bhakra Dam Project at an early stage (1943-45) Messrs. Morrison Knudson who were known to Mr. Savage had an early opportunity to study the Bhakra Dam Project. With the overall patronage of Dr. Savage, they set up a design office in Denver (called the International Engineering Co.) in which the specification, designs and drawings of the Bhakra Dam were to be prepared. In this arrangement they had a close opportunity of studying the details and they set their mind to bid for the whole project on a cost plus basis. According to them this was the only basis on which the risk of a foreign company could be covered, because there were so many intangibles in the Indian conditions—tax structure, import policy, dollar currency availability and even the stability of the Indian Government. As it happened, these conjectures of the year 1945-46 were followed by a political upheaval and the Punjab was partitioned into two States—a factor which was bound to influence on agreement that might have been drawn up between the Punjab Government and a company like Morrison Knudson.

An effort was made by the British Chief Engineers to secure Government approval to the contracting of the whole work (piecemeal) to the Morrison Knudson Company, but the tax structure could not be resolved. The foreign company had naturally to secure reasonable profits on their investment and know-how. With the high rate of taxation that they would have to pay, their quotations were far in excess of the estimate for departmental construction by Indian engineers supplemented by some foreign experts.

Indian Contracting Companies

Due to the novel nature of the job and many phases of mechanization which were unavoidable for the excavation, tunneling and concreting operations, no Indian firm of contractors was in a position to bid for the job. Any small experience for such items was limited only to a few selected Indian engineers who had been deputed by the State Government to U.S.A. for a study of the methods of design and construction ; that experience too was of a theoretical kind because none of the Indian engineers had previously purchased, installed and operated such machinery. Most of the Indian contractors had been so far working as labour contractors because the entire organization and management of the job was usually looked after by Government engineers. In the Railways and Buildings and Roads Branches, there were firms who took on codal contracts on through rates, but they were not big enough to tackle the Bhakra job because of its novelty and heavier investment needed.

Combine of foreign and Indian firms

It must be said to the credit of Messrs. Morrison Knudson that they explored the possibility of making a combine with an Indian firm. This arrangement would enable them to reduce their own risk and responsibility and the tax structure could perhaps be

somewhat simplified, but in the last analysis the money which could be taken out of the country by Messrs. Morrison and Knudson would be limited. But none of the Indian companies was big enough to assume the risk and responsibility which would be involved in the Bhakra Dam construction contract.

Machinery Ownership

The key to the entire question lay in the design, procurement and installation of the requisite construction plant, which was variously evaluated at 2 to 3 crores prior to devaluation. And along with the question of machinery were linked the problem of detailed design (including construction drawings) and the schedule of construction. The investment for all the construction machinery had necessarily to be of the Government because at that time, none of the Indian firms of contractors were developed enough to buy and own equipment. The precedent set up by the Hindustan Construction Company on Bombay's Water Supply (Vaitarna dam project) came up at a later date. It is to be remembered that pioneering work always involves some greater risk and gamble and as in other countries, the Government had to set the example.

Lack of initiative

The chapter of the first stages of the Contracting business in India has been largely composed of working as a labour supplier or material supplier on a small scale. Generally the departments of P.W.D. and Railways and Military Engineering Services have employed contractors for their maintenance works and of new constructions in which the work was more or less of a straight-forward nature and the contractors' quotations were either for labour items or so much percent below or above an agreed schedule of rates current at the time. The head of the contracting organization was generally a financier who had some hold on the local labour to whom he advanced money in time of need and whose headmen (jamadars) were developing skill in organizing teams of workers with proficiency in earthwork, or brick or stone masonry, concerte, steel work etc. In almost all cases, initiative and direction flowed from the Government engineers, who analysed rates, framed estimates and operated the management of government projects.

The above methods and tradition hardly left any initiative in the hands of the contractor. Seldom did the contractor employ an engineer or other technical personnel. Although he made a good living, he played second fiddle to the engineering staff and was more or less at their mercy. His initiative was there but rather of a restricted type. It is only in the recent years, that a few firms of contractors have sprung up who employ technical personnel and who are in a position to give firm bids for a job on the basis of unit price rates. This is a healthy sign because the development of the country can never rise to full momentum unless the private sector shows growing interest in the contracting business. This fact has been amply demonstrated in the case of the great strides that the building industry has made in the U.S.A.

Mechanization

In the case of the Bhakra Nangal Project, the work of the Nangal dam, Nangal canal and the Bhakra canals was largely done by contractors under all items where a large scale use of machinery was not required. For items like pumping, concrete mixing and large earthwork operations, the ownerships, maintenance and operation of the machinery vested in the departmental agencies. The rate paid to the contractor was based on analysis which excluded the working of machinery.

It is a well known adage that a contractor's organization is likely to be more economical than a Government organization for the management of routine works. Hence it is high time that the Indian Contractors follow the precedents set up by foreign firms and undertake larger and more complicated jobs on contract. The Rihand dam construction work has been awarded to Hindustan Construction already. The Bhakra precedent will have simplified processes and the experimentation done at Government cost will serve as a pointer for private contractors to enter the field with courage and confidence.

(*Continued from page* 6)

Harnessing of Resources

The basic factor which may be regarded as the harbinger of social upliftment is in the rise of the wage scale of the worker. With the improvement in the techniques with which projects have been planned and executed, there is a continual movement for upgrading of wages. The workers of lower grade gradually rise to the status of higher skill through their application and attainment in more specialised fields. Thus it is not uncommon for young worker who joins as a cleaner in a motor-vehicle to be a driver and then mechanic in the course of couple of years.

The situation has been created everyday in which a greater respect is attached to the fellow who can work with his own hands than to the merely degreed supervisor. This has been a good sign because greater production demands more workers who can turnout some work with their own hands. The pen-pusher and the observer do not make a commensurate contribution to the production. As a consequence, the social status of workers has gone up due to their increased capacity for being able to spend more on their daily upkeep. A visit to the project could not fail to impress even a casual observer that the workers feel social uplift and secure a better status for themselves and their families.

Technical feasibility of Bhakra Nangal Project

The multipurpose aspect of the Bhakra Nangal Project is its main strength regarding feasibility. All the water that is available in the Sutlej River has

been made use of for irrigation and power production. There were arid lands to the extent of 10 million acres which were in need of strengthening of their irrigation facilities either by supplementing of the available irrigation supplies or by making altogether new supplies available for the irrigation of the tract. Similarly there was a region which was starved for want of sufficient electric power and industry as well as other needs of the people were lying unfulfilled due to lack of power.

The irrigation aspect presented a sure field for expansion. The people of the region were well versed in this art and they had displayed great capacity for development of arid lands in the last 80 years. To them the value of the irrigation water was a symbol of magic that needed no further selling. It is mainly through the efforts of these people that arid lands will be developed and made the source of prosperity due to the rich yields from irrigated good soils..

Power aspect

The country's demand for power is now in the making. There is a wishful circle around the question of demand and supply in power undertakings. Unless there is ample power to sell, there are hardly any customers. If there are no customers, there is not enough financial justification for undertaking big power schemes. Thus the question of supply and demand keeps on militating against progress and the less experienced technicians and administrators can take the narrow view that the country should wait in the construction of power projects till there is a definite and substantial electricity demand.

There is an obvious fallacy in the above situation which has been brought home to the planners in the more progressive countries. It is universal that if more power is put on the shelf, there are more purchasers for it. With the advancement of technology, there is unmistakable spread of mechanization and the demand for power is, therefore, going to rise without any doubt.

Better Techniques

In the case of Bhakra Nangal Project, there is every reason to believe that the demand will be always in excess of the supply and the generation will not be able to keep pace with the load. This has already been demonstrated in the last three years and the load of delay alone has multiplied many times. Like private business undertakings, Government should be ready to take the courageous line and equip itself with higher generation potential than is indicated in the immediate future.

Fertilizer Factory at Nangal

The Fertilizer factory cum the heavy water electrical apparatus to it, be installed along with has been assessed to provide a load of 160,000 K.W. of firm power for the Bhakra Nangal. This is quite a substantial load. There will be thus an assured load from the very inception of the power plant which will yield a handsome revenue to the owner Governments of the Bhakra Nangal Project.

The technical and financial feasibility has thus been proved beyond all doubts. At one stage, it was considered that the very high rates of meterials and construction which were witnessed after the Second World War will cripple the financial returns from this project. This fear now can be safely dismissed although the very conservative financiers still try to make out that the returns from the project wil not be enough to make it productive at the end of ten years after completion of the project. Even if the financiers be right to some extent, it will be certainly conceeded that the benefits from the project in the general amelioration more than compensate for any low returns on the invested capital. It is high time that the yardstick in this respect is made flexible, so that the other projects before the country may be looked at more constructively than has been done in the past.

Other considerations leading to the undertaking of the Projects

Size

The george at the Bhakra site has a configuration that made it very suitable for the great height of dam—680 feet above foundations. Actually the height willl be somewhat greater due to the deeper foundations that have been considered necessary in order to provide for the treatment of the claystone member.

The size of the dam has been made suitable for the impounding of 7.4 million acre feet of water so that it it may be able to command the far flung arid regions of Rajasthan. The type selected is straight gravity as it ensures the maximum factor of safety. The conditions on the abutments were not suitable for an arch dam because of the jointed nature of the rock.

Aid Areas

The Hissar district is subject to famine conditions. Although the land is good, both men and cattle have perished in the past due to lack of any rainfall. Similarly, Rajasthan is suffering from extremely drought conditions and its irrigation on the lines of similar work done for the Bikaner State in the Sutlej Valley Project has demonstrated how quickly good results can be produced in that land if only irrigation facilities are made available. It was on these considerations that the height of the dam was raised to 680 feet instead of 580 feet which was contemplated in the earlier project of 1944-45.

Exploitation to the full

The sources of nature have been measured and exploited to the full in the conception of the Bhakra Nangal Project, as the first major work undertaken in the post Independence period. It is a tribute to the courage of the Government and the peiople of the country.

Organisation

The Bhakra Nangal Project is a huge one compared to the works with which Provincial PWDs are accustomed. Therefore, in the beginning, there was no idea as to how big the project organisation would be and how it has to be developed. This article deals with the growth of the project organisation practically from scratch and how it has broken new ground by way of operating methods and efficiency as against the old methods which were found extremely unsuitable and inadequate.

No revelation has emerged with greater force in the course of planning and execution of the river valley projects than the inadequacy of pre-independence scales of organization for tackling of projects. The principal factor which has influenced personnel employment for the implementation of the first Five Year Plan is the expenditure of about rupees six hundred crores for the river valley projects as against rupees one hundred and twenty crores spent in about one hundred years over all the river valley projects executed under British Rule. In the face of these figures, it is easy to understand that the previous ideas about the Governmental forces executing the projects needed a drastic revision.

The size of the organization is not the only criterion. More important than even the size is the fact that for big works one needs a big heart, courage of conviction and boldness to act promptly and effectively. In this respect Government machinery has to learn everything from private business methods where the value of decision is understood with all its implications. The business organization maintains a highly paid personnel so that with their vigilance and initiative production and scales multiply so as to earn bigger dividends inspite of all the overheads. It will be interesting to examine the status and procedure of Government organization and the handicaps that cause delays and wastefulness both in time and money.

Although there was a feeling that expansion would be required, a yard-stick and scale for such expansion were derived from previous experience. Whereas, the ratio of expenditure and target completion periods was somewhere ten to twenty times, the expansion permitted was hardly twice in many instances. Where the man in charge had greater push and pull, he succeeded in having somewhat bigger sanctions but even so the plans were hopelessly understaffed.

TVA, Bureau of Reclamation, Army Corps of Engineers

It is necessary here to acknowledge that a study of the projects and their organizations in other countries notably the U.S.A, led to some change in the narrow perspective. In particular, the T.V.A. with its momentous record of some sixteen dams constructed within ten years showed what could be achieved with proper planning and organization. This great venture which transforms the southern States, paved the way for similar accomplishments all over the world. Indian Engineers, who visted the T.V.A. works were greatly impressed by the momentum that had been achieved by the creation of the Tennessee Valley Authority. Similarly it was visualized that the great programme of the plan could not be accomplished unless India expanded her pre-independence organization into really competent units.

Need for Change

But the transition needed more than mere resolve to fulfil it. The grooves which had been formed in the 200 years of foreign rules, following in the wake of internecine bickerings and struggles had gone too deep into the soil to get easily obliterated. The planners wanted to get out of these but each successive step was eventually found to be too small. The period of the first Five Year Plan must be cited as one of trial and error. Some of the concrete examples which describe the measures adopted and their shortcomings and pitfalls make an interesting study.

The biggest hurdle was planning in a realistic manner. Time had not been of much consequence in many of the past river valley undertakings. Some of the masonry dams constructed in the South had taken ten, or more years. The Sukkur Barrage built in the British regime has taken as many as ten years. But some of the works undertaken in the Punjab had been quick—examples were the Trimmu Headworks in the Joint Punjab which took two seasons (November, 1937 to April 1939), and the Harike Barrage (October 1950 to June 1953). In the case of both these projects the speed was mainly due to the Engineers who headed the organization. In all other cases the schedules for planning, design and construction had been drawn out from four to five or even eight years.

Line Organization

It is most desirable that the completion of a project from the planning to the operation stage may be assigned to an organization which is adequately equipped with powers to implement decisions taken by competent authority. There should be delegation not only to head of organization but all along the line subject to periodic checks. But the principle to be followed should be such that the initiative is not curbed and liaison rendered so effective that immediate checks are possible to ensure that mistakes are not

made. In the case of Bhakra Nangal Project, the engineers heading the organization in the various States were generally Secretary to Government and they have their powers raised to much beyond the British period days. Yet it was felt that there are lots of gaps in their delegation and they were handicapped from implementing certain programmes. In this connection further decentralization of powers is needed not only to enable Chief Engineers to take prompt decision but also along the line so that the implementation of decisions is not delayed.

While framing the line organization the objectives to be secured are as follows :—

(*i*) Definition of duties.
(*ii*) Job description.
(*iii*) Dovetailing with the posts below and the posts above.
(*iv*) Definition of the sphere and conditions in order to reduce overlapping to the minimum necessary extent.
(*v*) Delegation of authority to enable every unit to be "self-inspired and self-propelled".
(*vi*) There should be frequent opportunities both at the informal and formal levels to examine and renew the organization.

Red-tape

A state of affairs can exist, particularly in Government organizations, when files move but the job does not move. Everybody is busy and even over worked but the nett gain is not proportionate to the effort spent. Quite a lot of forces of inertia and friction exist simply because the structure and operation of the organization have not been brought uptodate in the light of changed conditions. All such restrictive and unprogressive influences constitute red-tape. In democratic institutions red-tape has not altogether been eliminated but one can cut it down considerably and increase economy and efficiency.

Yardsticks

The Engineer's basic yard stick is the accomplishment of big work within the expenditure of least amount of time and money for the same degree of soundness and service from the said work whether it be a dam, a canal, a power house or a mechanical equipment. To achieve the object subsidiary yard sticks have been created depending on the nature of the job. These yard sticks must not conflict with the basic yard sticks. The subsidiary yard sticks should indeed be changed from time to time according to circumstances, so that they represent a consistent fraction of the overall yardsticks.

Regional and Functional aspect of an Organization

In non-mechanized jobs, the regional aspect of execution is logical because manual labour methods are already decentralized and, unlike mechanized jobs, do not depend on a central workshop for maintenance, repairs and overhauls. In concentrated jobs where mechanization plays an important part the functional control is superior to regional control as it leads to greater efficiency and economy, e.g. all concreting on the Bhakra Dam and appurtenant works would flow from the central mixing plants located at various key points. This would ensure uniformity in quality and strength within the desired limits. If this were not done the result would be dissipation of equipment and money.

Team needed at top

One outstanding factor is the selection of a proper team at the helm of affairs. We must have men of knowledge, experience and a well-tried reputation for imagination and drive. Again there must be no shirking of responsibility—rather they should have enough faith to welcome responsibility. Coordination and understanding of each other's difficulties should be the rule and there must be continuous personal touch with the job on the part of everyone, to enable quick and prompt decisions. Meetings and discussions round a table are to be preferred to correspondence.

First priority for Training of Personnel

The greatest need in the country is now for the training of personnel. And such training is not possible except by actual transfer of responsibility to the persons who have to be trained. Never has anyone learnt to master a skill by acting only as observer. The opportunity must therefore be seized of attaching selected engineers and other personnel to foreign specialists and experts and gradually transferring the full responsibility for the work to Indian hands. By this process, we shall have taken the first positive step towards ensuring the satisfactory manning of our development projects. And in this endeavour we must broadbase our selection of the candidates who are to be trained. The barriers of State and community must be broken and our choice should fall on those persons whose fitness for the skill is best as adjudged by their intrinsic qualifications, personality and aptitude. In the building of the Bhakra-Nangal Project works, such training is being automatically imparted to scores of young engineers and technical staff.

Role of Senior Men

In this venture of the new development programme, the senior men have a role to play. They must be willing to take full responsibility for taking big decisions. Even when there are some highly paid foreign technicians employed on a job, they must only be allowed to play the role of advisers and all the executive actions should flow from the Indian Officers who are at the top. By so doing they will be doing the best by the country in taking the full advantage out of foreign experts. In many of the decisions it is judgement and discretion at high level that counts. The technical details are no doubt important, but their significance is limited, and can be incorporated in the eventual decisions. But such decisions must be made in the consciousness that the good of the country and that alone is to be the guiding criterion.

New Principles evolved and Precedents established

The Government took a very bold step in undertaking the Bhakra Nangal Project at a time when partition had dealt a severe blow to the people. Stability of life and property was at a low ebb and the province had hardly recovered from the shock and hysteria of the calamity when the blue prints were finalized and rushed through. The results achieved have confirmed how wise and timely was the urge for the starting and completion of the unprecedented programme.

Naturally there is a limit to the certainty and precision with which the details of such a vast undertaking can be foreseen. There have been temporary reverses which were due to wrong selection of personnel and other external forces which were not suited to the requirements of such a project. But the main course of the stream has been pretty well maintained. The fruits of more irrigation and power are already in the hands of the people. And in the very process of the struggle, a new spirit and stamina have taken birth. There can hardly be any difference of opinion about the overall success of the venture. It has built in the Punjab a new back-bone, a new spirit, a new urge for raising itself to a height of progress and achievement in this revolutionary age of economic development.

Time is money: price of hold-ups

The new maxim which needs to be adopted alike by engineer as well as audit is that time is money and nothing is so expensive as hold-ups and delays. In most cases, more than one solution is possible and the difference between some of them is inconsequential. The success of management (technical and administrative) consists in giving the decisions in a firm and unambiguous way, so that the wheels of progress are not slowed or stopped. The time lost in indecision creates a slogging and rusting of the whole machine, and the damage is much deeper than can be seen on the surface.

In the case of the Bhakra Nangal Project much time was lost in the early stages. The decision regarding the alignment of the Bhakra Main Line below Rupar and subsequently the choice of specifications for lining (whether concrete or sandwich type brick masonry) consumed weeks and months, and retarded the pace of planning and construction. The finalization of the construction plant layout for the Bhakra Dam and the selection of equipment also took years. Some of the vacillation can be ascribed to lack of experience but the consciousness that delays are dangerous, needs to be recognized all along the line, like the importance of sanitation and laws of health. This would change the climate and infuse vigour and urgency in the entire organisation.

People expect prompt execution and service

The awakening that has taken place in the masses is reflecting itself in the caustic comments that promptly follow any bungling on the part of the authority in charge. This is just as it should be in democratic set-ups—only education of the people should be guided by the true exposition of the nature and difficulties of engineering projects. But the exposition of mistakes by healthy criticism is to be welcomed rather than suppressed.

In many of the cases, however, the reasons for delay are beyond the control of the engineering authorities, e.g., acquisition of land or the finalization of an alignment in which various parties of the public are involved. It is here that enlightened opinion has to be created to understand the implications and the loss to the community due to the intransigence of any individualistic interests. This would smoothen the issues and enable quicker decisions.

Lack of Personnel

The Bhakra Nangal Project is perhaps the earliest major undertaking in the country's river valley projects, where the hurdle of inadequate personnel had to be faced. Till 1944, the joint Punjab Irrigation Department had executed some memorable diversion weir projects of which the Haveli Project (Trimmu Barrage), and the Thal Project (Kalabagh Barrage) were notable examples. At these projects, the flood discharges of the river harnessed were 7 lacs and 10 lacs cusecs respectively. The former work had been carried out with unprecedented speed and economy and won great recognition for the team of Indian engineers, who, for the first time, were given the opportunity and responsibility for constructing a big headworks and canal system.

Both these projects, large as they were as diversion schemes, had a diminutive stature, as compared with the colossal Bhakra Nangal Project. The cost of the Haveli was about 3½ crores and of the Thal about 12 crores (according to the then estimates—period 1937-1946). The Bhakra Nangal project was at that time estimated to cost about 85 crores for the 580 ft. high dam and Rs 140 crores for the 680 ft. high dam. These figures have had to be subsequently increased due to various causes—devaluation, higher cost of Indian materials and labour etc. The Bhakra Nangal Project now stands in the neighbourhood of Rs. 165 crores inclusive of the left Powerplant 5 generating units. Thus the size of the project demanded, at the very outset, a considerable expansion of the engineering and other personnel, if the results were to be achieved with the same degree of efficiency and economy which had been evidenced in the case of the Haveli Project. This meant that the establishment should be expanded some 12 to 15 times, as compared with the personnel who designed and executed the Haveli Project. While suggesting this figure, a multiple of 3 has been adopted as between the 1939 and 1955 rates—these dates are a reasonable base for the comparison of the two projects.

Narrow Outlook had to be transformed

Although the above argument is based on simple arithmetic, and any business organization charged with the construction of such a big undertaking would have arrived at the obvious conclusion at a very early stage of the planning, Government departments which have to function under a democratic set-up, could not be so bold or flexible as to embark on an expansion so rapid and so unprecedented. Every new post had to be administratively and financially justified. Going through the maize of several departments in the Secretariats of four Governments, the proposals of expansion took their own time, although the final result was much the same. How much the country would gain if decisions connected with development projects could be taken on the basis of a scientific analysis of the work load and the capacity of an individual in the various units and categories of planning, design, construction and administration.

Not yet "dam minded"

Once Dr. J. L. Savage, the Chief Design Engineer of the Bureau of Reclamation, U.S.A. was consulted on the question of personnel. The Chief Engineer

A view of the Bhakra Dam region

incharge of the Bhakra Nangal Project was at that time leading a team of some 30 engineers, "Shall we need twice or even thrice the number," he asked. "You will need 10 times this number or more" was the jocular reply. Such a figure was, however, not taken seriously. In actual practice, it has been realized, that at the peak of the construction programme, the total number of engineers (including foreign specialists) engaged on the Project has been as high as even 400, thus exceeding even the figure which Dr. Savage was believed to have mentioned in an informal discussion.

Working to Schedules

The key to the whole question of personnel is provided by the fact that if each operation is planned and set in proper sequence to achieve the completion of a project within an optimistic time limit, the requirements of personnel assume proportions which are much beyond the usage and experience of the working of Public Works Departments in this country. The reason is not far to seek if one compares the nature and magnitude of the achievements so far made with the type and volume of work comprised in each of the several super projects which are now in hand in the country. The conclusion becomes apparent to even a casual student that in the interest of overall economy, it is more advantageous to speed up the tempo of the work by the employment of more hands at one time, than of letting it drag and linger on because of lack of supervisory and executive personnel.

Practical skill and specialization needed

The biggest pitfall in the process of manning of the Projects (and specially of Bhakra Dam Project) has been the lack of experienced mechanical engineers. The system of education in our engineering colleges has been centred on an emphasis in theoretical and academic engineering rather than first hand knowledge about the handling and operation of construction machinery. The British engineers, whose role in the history of river valley schemes is certainly creditable, have been known to concentrate responsibility about the selection, management and operation of machines in the hands of their own race. The result was that the bulk of Indian engineers played a rather subsidiary role—although their stature showed far above some of their foreign contemporaries inspite of patronage and preference having been made a privilege of the ruling tribe.

Special difficulty of Bhakra Dam and its solution

In the case of the Bhakra Dam, it was realized within the first few years of the construction, that the solution lay in the judicious mechanization of the operations. The gorge was difficult and narrow from the access and space point of view, and the economy and success of construction lay in the coordinated mechanization of the operations of excavation of rock, haulage of muck, transportation of aggregate, manufacture of concrete and its placement and finish. Since the problems of foundation and design had some uncontrollable uncertainties, the job could not be let out on contract except at a fantastic cost plus price, it was decided to execute it departmentally, by the employment of an adequate number of Indian engineers conjointly with about 1/8th the number of foreign experts who were hired for varying periods.

The procedure has worked successfully. Besides the guarantee it has given of sound and quick execution, it has also enabled a large number of Indian personnel to be trained in all fields of construction, thus ensuring that the requisite skill will be developed and created within the country, and future projects will be entirely managed by Indians in all spheres. This is a great step in the development of the country.

Some officials overburdened

It has been realized in the case of the Bhakra Dam Project that there must be adequate personnel at all levels to initiate, operate and supervise the various stages of the work in all departments. Also the delegations to the men in charge of the work must be adequate to permit a suitable playing of initiative, so that the achievement is commensurate with the position held by the workers. When the time organization was evolved the various items of work were broken or impeded at any level. This principle, however, needs a vigilant watch and continuous implementation, because the efficiency of an entire team can sometime be marred by one individual becoming the bottleneck for the streamline flow. No matter how heroically this overworked individual works, he cannot for long maintain the efficiency or best progress of the group. This fact is now being realized in an increasing measure and more delegations are being passed on to the next-in-command. The result is good for all concerned.

Rules of Recruitment and Termination inelastic

The present rules of Government service were found to be rather too rigid for the cultivation and display of the qualities of initiative and leadership in handling of situations. Under the rules it is neither easy to reward a man for his outstanding work, nor can one impose summary penalty for slipshod performance. Whereas stability of one's job is a big attraction for the good and efficient hands to join Government service, too much of stability leads to inertia and rigidity. In the case of the Bhakra Dam work, recruitment from the market has been made on a short term basis to supplement the regular staff. The new employees have been given starting salaries which are commensurate with their market value. They are passed through some initial tests and then given training in the particular branches where they have to serve. In the higher ranks, Indian technicians and Engineers have been recruited as Junior Specialists and Senior Specialists. It was difficult to find men of the requisite experience and the best available men had to be hired. The result is a mixture of all types—but the average stature has fitted in the organization after intensive training imparted by Indian and foreign experts. The next project will reap the full benefits of the training given.

Foreign Specialists

The subject most debated on the Bhakra Dam project, in the press and Government circles alike, is that relating to foreign specialists. Many people repeatedly ask : Were foreign experts necessary ? Why have so many of them ? And why pay them such astronomical salaries ?

Why needed

The answer to the first question is not far to seek. When an unprecedented job alike the 700 foot high Bhakra Dam has to be built, it it not wise to rely on experimentation and chance and trial and error for its overall safety and economy. The stake is too heavy to permit of such a procedure even if it was practicable. One cannot make it a matter of prestige or I-know-all. The lessons learnt in the school of experience cannot be mastered by only relying on books or reports or second-hand observations. The importance of the Bhakra Dam is a concern of the whole country and the engineers of one State would have been accused of arrogance if they claimed a monopoly of knowledge or capacity to do such a job. And without the help of foreign experts they would have made mistakes, which would have cost time, money and may be the reliability and the safety of the dam itself.

How Many

Accepting the necessity of foreign experts in the set-up of departmental working, the question that crops up is the number and stature of such experts. This has also been a much debated question and the controversy has still not reached its end. The conflict of opinions has been vast and has ranged at all levels from the engineers themselves to the public and the Ministers-in-charge at the State and Union level.

Happily for the job, the achievements of each year have demonstrated the wisdom of the arrangement. The methodical and clockwork like progress has shut many a critical mouth and won over even those who were bitter opponents at one stage.

The key to this conundrum lies more in the rate of progress and the tempo of the schedule than in the mere number of foreign experts employed at any stage. And the basic factor which needs to be understood is that the brunt of the responsibility is, all the time, devolving on the Indian personnel. This is just as well, because in the event of the foreigners leaving due to any reason, the job must go on as efficiently as possible. Once this principle is accepted, the entire situation assumes a different aspect, and even the so-called excess in the number of foreign specialists goes into the background. It has to be appreciated that failing departmental construction with the aid of foreign experts, the job would have to be contracted to a foreign firm—American or French. Such a firm would have undertaken to do this 65-crore job on a fee or a cost plus basis and their profits would have not been less than 8 to 10% on the entire job. The country would have had to pay a sum of about Rs 5 to 6 crores to the foreign firm. It is expected that the total establishment charges on the Project including the pay of foreign experts will be well within this figure. And a distant advantage which could have accrued only under the present set-up is the training value for all the Indian personnel. The value of such a training, in the context of the numerous river valley projects which the country has still to undertake, can hardly be assessed in terms of rupees, annas and pies.

Functions

We might next examine the functions allotted to these foreign experts. In the majority of cases, these men have not been selected on the strength of any academic qualifications, but on the score of the construction experience that they had acquired while engaged on similar jobs. As such their know-how is of direct utility and the Indian counterparts who are

working alongside with them, derive the advantage of discussions and direction of operations ranging from the upkeep of a shovel to the main scheme of diverting the River with an economical sequence of constructing the mammoth cofferdams. The fact is not much advertised, but is known in all responsible quarters, that if the advice or opinion given by the foreign experts is not in accord with the overal merits of the problem (which contingency cannot be ruled out on account of the difference between American and Indian conditions) then it is examined objectively and rejected in a courteous manner by explaining the reasons which make it unacceptable. Conversely wherever their advice is an improvement on existing practice, it is accepted and meticulously followed even by making drastic changes in the customary procedures. By so doing, a real spirit of comradeship and team spirit is built up and the best value is got out of two collaboration. The traditions developed are healthy for the real benefit of the project and a sense of self-confidence is fostered in the Indian personnel, so that they can shoulder the full responsibility on their own in the earliest possible time.

Salaries of foreigners

A great deal of adverse criticism has been aroused against the relatively high salaries (Rs. 4000 to Rs. 5000 per month tax free) which have been paid to the American personnel hired on short term contracts. But the fact that needs to be remembered is that no foreigner would be ready to quit his hearth and home unless he got appreciably more emoluments than he is able to earn at home. Judged by this criterion the salary set-up for foreign specialists at Bhakra loses that fantastic complexion, which has been ascribed to it. When we have purchased costly and intricate machines of colossal size and delicate mechanism, we must ensure their safe and trouble-free working. To stand on ceremony or an exaggerated sense of prestige would have been inviting risk and delay which would also have cost money. Also if the work was given to a foreign contractor we would have to pay him his reasonable profit, and the training value of the work could have also been lost. For any subsequent job of a similar nature we would again have been too weak to take the full responsibility and there would be a tendency to let out the job on contract again to foreigners. The total sum paid by way of salaries to foreigners on the payroll in departmental construction is not much in excess of what the contractor would have charged by way of his overheads and profits in a cost plus agreement.

The price of mistakes

And who can assess the price of mistakes that would have been committed in the planning, design and execution of this first undertaking of this nature and size. It is good to learn through the hard school of experience when the stakes are not so high. But when the safety of a high dam and the irrigation and power dependent on it is concerned, it is best to be conservative and to err on the safe side. Even under the present arrangements continuous studies, scrutiny and vigilance are needed to secure the best results for the investment of time, effort and money.

Positive Achievement

The angle of establishment charges by itself is in the long run found to be a narrow one, in the context of the total achievement. The co-ordinated value of experience and a scientific approach covering the various fields, is not strictly measurable in terms of money because one year's earlier completion of the project brings in its train all the benefits which would otherwise be delayed. And the value to the region and the country of the earlier production of food and cotton and earlier availability of big blocks of hydropower is immense. The one gain which can safely be expected is the quicker completion of the job and ensuring the soundness of the various operations of design and construction. This is achieved by coordinated effort, guided by experts who are in a position to make use of academic and scientific knowledge as distilled in the processes of their experience gained from the various jobs of similar nature.

In the case of the Bhakra Dam, a balance has been secured between theoritical and practical considerations. The old precedents are re-examined in the light of new conditions and consistently with the limitations of local material, personnel and concurrent use of machines and men, the complicated stupendous job is being pushed on in the various phases. It cannot be claimed that this is the only manner in which it can be done but there is no doubt that in the present methods, the optimum use is being made of the resources of the country augmented by the know-how of modern techniques.

Gaps and how to fill them

When the Bhakra Dam Project requirements were critically examined in 1945, it was soon realized that between the knowledge gained from books, office discussions etc. and the actual execution of the job of 50 foot diameter tunnels through difficult rock, there was a large gap. It is not so much in the general arrangements of a project, but the detailed design and construction requirements that one misses the hand of prior experience. The position accepted was that, undoubtedly, the experience of irrigation engineers in the Punjab was sound and long enough to start the undertaking but it was desirable to supplement it with new knowledge and additional information in every possible way. Thus certain engineers were given the opportunity of visiting abroad and seeing these works first hand. A project was then drawn up on the basis of Indian practice. Other important issues regarding design were examined in design offices and hydraulic laboratories of foreign countries through association of consultants like Dr. Savage of the United States Bureau of Reclamation. The work thus started gained momentum notably on the Bhakra Canal system and Nangal Hydel Canal project and Nangal Dam, success came by following the methods already known. In the case of the Bhakra Dam, the progress was slower than had been hoped. Difficulties in designing the details of the tunnels, dam, appurtenant works, powerplant etc. on the one hand and the layout of the construction plant, on the other were acknowledged. In the case of the construction plant in particular, the biggest necessity was of a co-ordinated layout, as the dovetailing of the various items of equipment in respect of operation capacities and maintenance were to be given paramount place. For this purpose, a number of experts were contacted and employed for short periods, but the time was not yet ripe for a final attack on the entire job due to, one might say, lack of previous experience and imagination. The role of constultants

was recognised to be important from the very start. Indian engineers connected with the project prepared their reports on the intricate items of the design bringing out the special characteristics of the site and properties of the material as determined by a series of progressive tests in the field and laboratories. Simultaneously exploratory drill holes on an extensive pattern were made and the stage was set for the working out the final solutions.

Consultants

Whether foreign engineers or Indian engineers were put in responsible charges, it soon became apparent that some of the problems were so intricate and important that the large stake embodied in the Bhakra Dam warranted the employment of a Standing Board of Consultants. This was accordingly raised mostly from the United States of America where works of similar magnitude have been executed in the recent past. In order to get the best value out of foreign consultants, the study of the problems, within the country became most necessary. The excellence and the finality of the solution suggested by the Board of Consultants in a large measure depended upon the data which was unearthed and presented to them in the meetings, at site. This mode of working yielted happy results because all important problems were properly thrashed out, and the picture that emerged left no room as to its soundness and overall suitability.

Best solutions from alternative examinations

The gaps that needed to be filled urgently cannot be enumerated specifically. But as the work has progressed, the development of skills and efficiency has facilitated the further working, with added progress and competence over many new problems that must continue to arise in an undertaking of this nature. It will be interesting to mention some of these aspects in a broad way :

1. In the field of designing, the engineers set their own hands to the drafting tables and the work of designing, calculations and drafting was tackled by them personally on the same lines as it is done in the Bureau of Reclamation. This helped in improving the quality of the work as during the stages of detailed drafting many new ideas are evolved with consequent advantage to the soundness and economy of the resultant job.

2. In the field, the installation and operation of big machines became the personal individual responsibility of the several Indian engineers who were incharge of different phases of the operations. Many of them rolled up their shirt sleeves on the example of the foreign technicians hired for the job. The result was highly fruitful in all requisites, and soundness, operation of machinery and efficiency of performance appreciably improved.

3. A great reduction had to be made in the excessive time and effort that according to departmental rules and traditions, had to be spent by all officers sitting on their office desks. It was concluded and urged that engineers must devote the maximum amount of time to their technical duties whether in the field or the design office and routine correspondence and accounting should not be allowed to take away from their real function and utility. All accounting and personnel work were concentrated in the charge of Administrative Officer and the Chief Accounts Officer. The results have already appeared in the simplification of the accounts although a further evolution along these lines is necessary to bridge certain gaps and to overcome certain hurdles.

Schedules

The important idea that soon found its place in all branches of the organization was the scheduling of work. This meant that the total quantity to be dealt with was accurately determined together with the period in which it had to be completed. The targets of time were then marked and man-power and material position assessed so as to realize those targets. In this process of planning, some of the bottle-necks and weak spots came under the lens thus enabling the authorities to augment their resources and personnel. This scheduling habit filtered down from top to bottom, in all departments and an integrated system of phasing the work soon prevaded the projects. For this reason it became possible to predict the completion of the job in point of time and cost very much more accurately than heretofore.

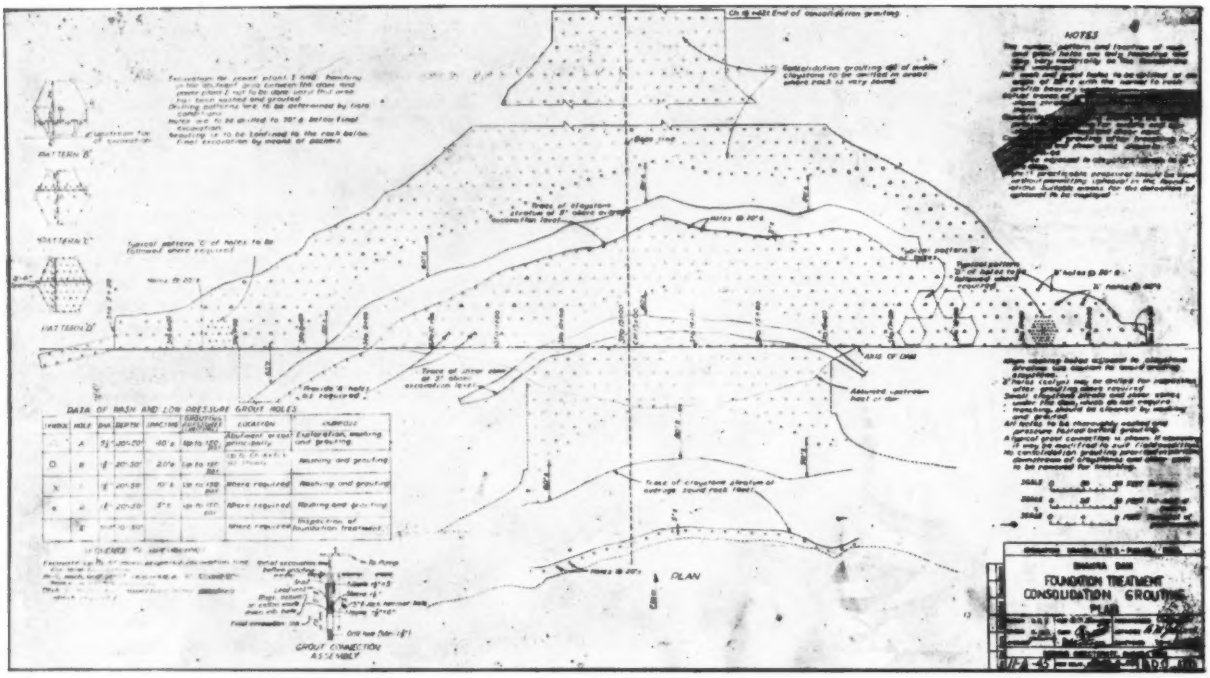
Recruiting Agency

The one factor which proved to be the biggest hurdle was the raising of sufficient personnel. The size of the job and its departmental execution demanded an expansion which was beyond the boldest conception of departmental authorities. The Public Service Commission of the Union or the States could hardly keep pace with the necessities of recruitment and special delegations had to be vested in the Control Board and management to explore and hire personnel who would fill the demand. The matter was given continuous follow-up through advertisements and personel visits of senior officers to other Projects and recruitment of about a 100 officers and foreman was made for the various functions. The result did not give positive benefit immediately as most of the hands so recruited needed further training. But the beginning made bore fruit in a few months and the position regarding personnel appreciably improved. The same process is still going on although it is an accepted matter of policy that wherever the requisite know-how and skill are not available within the country, this may be obtained through a short term hiring of foreign personnel.

As explained earlier, the cost of such experts with the importance and value of the service performed has more advantages than disadvantages in the balance. Not only is the Bhakra Dam being built but the foundation is being laid for training of scores of engineers and technicians for undertaking similar jobs all over the country in the development plans of the next few decades.

After the Project what : Temporary engineers

The prospects of 2 to 3 hundred engineers who are employed on the project in a temporary capacity have to go out after the completion of the project in 1959, is a dismal one. There is hardly any doubt that in the context of the country's continued programme, there will always be a demand of trained engineering personnel, yet the cadres of the State Governments do not permit them to recruit the engineers on permanent basis. This is due to the fact that no State is in a position to guarantee permanent employment



Foundation Treatment and consolidation Grouting of Bhakra Dam

to such a large number of engineers when its major projects like the Bhakra Nangal Project is over. The position is certainly unsatisfactory from the point of view of temporary engineers and other personnel. They have a constant fear of retrenchment hanging over their heads and this factor does not permit them to give their very best to the project. On the one hand there is hardly any doubt that these members of the staff have valuable experience which enhances their market value.

Workcharged employees

The same situation is also applicable to the workcharged employees. Although these workers are engaged for shorter periods and on lower scales, yet there are some amongst them whose experience and capability make them quite indispensible for the execution of similar works. It is of the utmost importance that continuity of service is ensured to these employees because the same is in the interest of the country, the Government and the individuals.

There has to be much greater flexibility in the cadre of the regular services. Why it is not possible that good workers are ensured continuous employment for ten years so that they may not have to worry for their jobs, and their best energies may be directed to the fulfilment of their duties in a care-free and courageous manner. In the implementation of the 2nd Five Year Plan, this aspect deserves to be given the foremost importance.

Foreign Specialists

So far as the Specialists and Consultants from abroad is concerned, it is important to note that firstly they make the contract quite lucrative to themselves. Secondly if the Government default in the performance of the contract they are entitled to all the advantages of the contract clauses under which they can draw full pay for the unexpired period of the contract. Also for diplomatic reasons and in the interest of international reputation, the Government have to be rather lenient employers because they are anxious to retain their good name in the international field. It is highly important that the conditions of employment of Indian personnel should be on a just and satisfactory basis for the workers also. In this way alone can the best contribution be obtained from the employees.

Other Projects

The solution evidently lies in further projects being got ready by Government in time so that the switching over from one project to other is done on planned basis. In the case of the Bhakra Nangal project, the period for which the staff remained continually employed has been rather short, although this was one of the biggest river valley projects in the country. The best utilization of personnel and equipment can only take place if the planning is done on firm basis and every worker and every machine gets earmarked for their next position at the proper time. This policy has been talked about in many sessions in the Seminars, Central Board of Irrigation and Power meetings, and Institutions of Engineers. However the implementation of such a policy is still not clearly in sight.

Continuity of employment

The above factors make it incumbent on the Planning Commission and the concerned Ministry of the Government of India to pronounce a clear-cut policy so that the very much valued and experienced personnel of one project are not lost to the subsequent projects. It will not be any exaggeration to say that if this factor of continuity of employment is secured then an atmosphere of health will prevail on the country's projects.

Planning

In the planning of this project there has been the usual experience of costs leaping beyond the original estimates on several occasions. The constant struggle between the engineering wing and the finance wing is reflected in the article which throws a flood of light on the traditional codes and practices which have been cramping the work of the engineers. The problem of control of the actual operations and economic management by the engineers are discussed and improved methods suggested.

The Bhakra Nangal Project constituted a model scheme for planning of the various phases of the project. It comprised all types of works ranging from a minor channel to the second highest dam in the world. It also included a number of modern power-plants in which generating units of capacities varying from 24,000 to 90,000 K.W. each were to be installed.

In the course of the preparation of the project various factors kept on arising from time to time which necessitated modifications (generally extensions) in the scope of the project. It is very interesting to see how this project initially started with an estimate of about Rs. 40 crores had to be increased to over four times this amount. The reasons for each modification were indisputable, although one wished that the project had at the outset been conceived and presented over a larger canvas so that the public may have felt less non-plussed over the repeated revisions of estimates and postponements of the date of completion.

To secure this condition, it is very important that the persons incharge of planning act with bold imagination. In a project of this size where the completion of the works takes one or two decades, the public needs to be continuously kept reminded of the eventual and ultimate potentialities which can be realized by the completion of the project according to a bold plan. The work of development of the country in its present phase makes it axiomatic that the bolder the scheme the greater its utility and appeal for filling the large gaps of economic backwardness which have been the fate of India over the last few centuries. In such a perspective, imagination and creativeness pay large dividends and it is most important that people with a shrivelled outlook should not be appointed leaders.

The financial yardstick with which the success or otherwise of all planning can be measured must necessarily be realistic and elastic. The ultimate aim of a development project is the increase it can yield towards greater production, greater employment and better living standards. We must not forget this aspect in any of the major decisions that have to be taken. There is nothing sacred about a blueprint previously drawn as long as we can improve the same blueprint in proper time, on account of new ideas or suggestions that grow around the subject while active work progresses on the project. The success of a government or a regime is to be measured by the final results and not by the avoiding of changes in strategy or implementation that become necessary while the work is in hand.

Small economies for their own sake have very little meaning in a project of this nature if by a fractional expenditure much greater wealth can be created in the shape of end-products. In fact there should be encouragement for suggestions which lead to improvement of the scope, quality or efficiency of the work while it is in progress. It is always in an atmosphere of appreciation and recognition that the greatest effort becomes available for the success of the management. At the same time it is important that every change or modification is supported by proper argument and realistic assessment.

In the case of the Bhakra Nangal Project, the original conception of making the dam only 400 ft. high gave place to the recommendation that the Bhakra Dam can be built 680 feet high. With this change the total live capacity of the reservoir was more than doubled. The same applies to the increase of power potential. In a region which is suffering from famine and want, the standards of production cannot at all be raised to the requisite degree unless a colossal increase is made in the use of water and power. The changes made in the Bhakra Nangal Project were all for securing greater development with the expenditure of a relatively smaller amount of outlay. The over-all result of such a flexibility is favourable provided the public and the authorities are kept fully informed of the reasons for the changes. It is no discredit for the planners not to have foreseen every possible change at the very outset. In such large works, the data clarifies only when we are half way through the game and it would be unscientific not to take advantage of the new factors that come to light.

The same does not apply to bottlenecks or other handicaps which retard the consummation of a project. These are due to the imperfection in rules or procedures or too much red-tape or lack of flexibility even when the work demands that the old rules be modified. The private sector enjoys the advantages of fullest initiative at all levels. This alone can lead to every one in the organizaton taking fullest responsibility.

View of down-stream pilot Cofferdam for enclosing the foundation area of Dam.

Government offices must adopt the methods which make the private sector efficient. No formalities should be allowed to stand in the way of quick exchange of ideas and prompt decisions which are facilitated with such exchange. Similarly the restrictions on the strength of personnel on the basis of previous sanctions need continually to be reviewed with a courageous mind. Ample staff has to be provided so that it is in proportion to the bigness of the undertaking. In the case of the Bhakra Nangal Project, the authorities came to proper conclusions after having lost a good deal of precious time. The staff was then expanded three to four time to attain the targets of progress. It is only through this expansion that the achievements of the target dates of the project was made possible.

Hurdles for their own sake

Other bottle-necks are in relation to rules of procedure, particularly finance. Whereas finance and audit are the essential organs of the project to ensure economy and genuineness of expenditure it is also necessary that they share the fullest responsibility with regard to the completion of the project within a specified period. Hence the effect of each of their suggestions or inhibitions is to be interpreted in terms of the delay that the procedure will cause. It is therefore for the audit to so modify their rules that the pace of the achievement is not retarded. It should be possible to effect these modifications as required in the interest of a specific project by a mutual consultation with the authorities in charge of the planning and construction of a project. Lately this view is being increasingly supported by the administrators and the finance and audit departments.

Saving in completion time

In the last analysis, there is no procedure which can offset the value of lost time. The completion of a project like the Bhakra Nangal Project one year in advance of the targets means one year's additional income to the Nation. The human value of such an advancement is hardly calculable in terms of money. As such the highest stress must be on the saving of completion time of a project. This is always done in countries where the public sector has a complete charge of the planning and construction of projects.

Underestimating and Excesses

The question has been continually asked "why are

the estimates of oost of the Bhakra Nangal Project continually revised and increased?" This is very understandable enquiry, particularly because the public started to hear a figure of Rs. 80 crores in 1945 and the same figure is now revised to 170 crores. There is thus over 100% disparity in the figures first given and now quoted. A word of explanation justifying the increase is of the highest interest to the people who are the payers for public works in the ultimate analysis.

Lack of Touch

The main cause of adverse criticism of the public over a situation like the above is the lack of contact between the Project management and the people. In these days, the common man is quite concerned about the efficient and economical execution of the projects of his region. Also he has no prejudice against revision of estimates, provided the reasons and purposes are explained to him concurrently with the progress of the work. Thus in the case of the Bhakra Nangal Project the causes of excess were as follows :

1. Devaluation of the Rupee in relation to the dollar.

2. Raising the height of the dam by 100' (reservoir elevation raised from 1580 to 1680) to get more areas under irrigation.

3. Increasing the scope of the Project for irrigation and power.

4. Advancing the programme of installation of generation units.

All these changes and departures from the original estimate have been examined by experts, (engineers, administrators, financiers and public men—elected representatives of the people) and approved at some stage. Yet the public are in the dark about the details and they come to know these through newspaper stories in which the basic details are not always given in a self-contained manner, thus leading to suspicion and unjustified criticism by the public and indignant explanations from the wronged project authorities.

Causes and explanations

In an ideal arrangement, the causes for revisions and excesses would be discussed openly with the public and their understanding and support will be automatically forthcoming. In many cases the full data for the preparation of a project is not forthcoming at the time and the engineers has to rely on guesswork based on certain assumptions. If these assumptions do not mature, the figures have to be unavoidably altered. It appears that in their anxiety to secure approval of projects and to get a name for economy and efficiency, some of the engineers have been under-estimating the difficulties and their financial forecasts have proved too rosy. It is high time that the public and the Governments are given a range of Project costs with a minimum and a maximum depending on the actual conditions. Then they would be more alive to the inevitable necessity for changes as the work progresses. If the lower figure proves unworkable, the saving compared with the higher figure will be an index of the skill and efficiency of the engineers. The The public will also get used to looking at the reason behind rather than the superficial picture.

Finance and help to produce more

The policy of finance where investment is made in productive schemes is the only policy that will eventually solve the troubles of this country. In agriculture and hydropower the total capital investment is made up in the very early stages because there is so much demand for water both for irrigation and power purposes. The history of the Lower Chenab Canal of West Punjab demostrated that the capital outlay was repaid 12 times over in a brief period of 25 years. The same will apply to the Bhakra Nangal Development in principle. At the moment there is underestimation in respect of the electric load. As soon as the policy of expansion of industry is implemented there will be a very much increased demand for electric power and the result is bound to be much the same as was experienced in other countries who have embarked on a policy of industrialization. Government is a going concern and the financial wealth is synonymous with the will power and the labour of the people. If conditions are created in which people can work to their capacity with enthusiasm, it is as good as the money in bank. It is precisely this climate which is now being generated by the lead given by Goverament in the planning of development and the results have been reassured than predicted.

Restricted outlook on progress

The worst hurdle in the process of development is a narrow outlook. Financial yardsticks are no doubt required to be conservative but if they are not imbued with the spirit of realistic achievement they are bound to retard the development programme in the country. The investment in productive work can only create wealth if properly invested. For this purpose let all loopholes be blocked and the works made more scientific and sound rather than spread negation in the path of further progress.

As there is a trend in the country amongst some of the less progressive sections that a certain amount of laxity prevails about the proper exteat of public funds. Financer is apt to look upon everthing with suspicion. It may be alright but their application should be made with judiciousness so that no unnecessary hurdles are created for this race of industrial development.

Finance as tool and not as master

This undertaking differed from the previous projects of the country primarily in the context of power generation. Each drop of water was to be conserved and regulated aso as to fetch maximum benefit in the dual purpose. There was to be a big lake for storage of water in summer months and lean year, and the same water was subsequently to be released to serve the largest area of crops, and to generate maximum firm power. For this reason, the safety of works and the certainty of controls assumes a new proportion. This has been translated in the relatively new type of structures which constitute the Dam, Headworks, Powerhouses and Canal Syphons and Super-passages. The type of construction adopted is modern with an emphasis on concrete—mass and reinforced.

Reasons for different approach

The origin of public works on river systems is wrapped in the history of training of rivers in the vicinity of the "Headworks" from where irrigation

Diversion Tunnel—concrete lining completed on sides

supplies were taken off. The Headworks were made of stone crates and boulder masonry till the early nineties. The more vulnerable portions like the under-sluices and the canal head regulator were usually constructed with ashlar stone chisled out of hard granitic rock or other durable type of stone. These processes involved hand labour of masons and coolies to produce the fine dressing. Carriage was arranged by pack animals ranging from elephants to donkeys. There was generally no insistence on works requiring years to be done in months. The arrangements for works were made on the basis of available materials and labour and if certain projects took 10 or 20 years to build it could not be helped.

This is not the present day angle. The Bhakra Nangal Project has been geared for a completion time of 5 years for canal works and 10 years for the dam. And this is made possible with a substantial degree of mechanization in the several processes. If machinery was not incorporated in our construction techniques, we would till be unable to improve upon the outturn and speed of the last century. But now the job is a function both in cost and speed, of the degree of mechanization. Hence the methods which proved successful in the past ceased to be applicable in the new type of works like barrages fitted with steel gates and hoisting mechanism. This situation was heightened all the more when we came to high dams fitted with all modern appurtenances including steel gates, penstocks, outlet works and power plants.

Labour wages

The major change that has come about in the economy of construction operations is the much higher scale of labour wages which have now to be faced. The rise that has taken place in the last 25 years is three to four times—and this is now a permanent feature. It is not unwelcome considering the necessity for raising of the living standards of the common worker. But the projects of the present and future have to be financially feasible and remunerative, and this requires economics in all stages of the Project. Thus a careful comparison has to be made in the alternative ways of execution. Due to the diversity of machinery now available for various operations in the Project the range of permutations and combinations has correspondingly increased and a higher degree of skill and experience are called for to evolve the best solution.

Tempo of progress

With the introduction of machinery in the various phases of work, the speed of execution has undergone a unique improvement. The outturn of earthwork and excavation with Shovel-Scraper, Bulldozer, Tractor combinations and the output of concrete with giant plants for manufacture and processing of aggregate and batching and mixing plants has gone up to levels which were quite unattainable with manual methods. The results has been the cutting down of completion time to one-third or one-fourth. And, accurate forecasts have to be prepared for keeping all the units of machinery employed for the maximum time to maximum advantage. The old procedure, rules and sequence of financial authorizations have, therefore, become obsolete. Since no concerted effort has so far been made to overhaul the old codes and bring them into line with modern requirements, we have a continuous disparity in outlook between finance and audit on the one hand and the engineer and administrator on the other. The target period for the completion of the project which is clearly a vital factor in the overall economy is allowed to slide back and the substance is lost sight of while never ending arguments fill the files apportioning blame for commission and omission. One cannot help feeling frustrated, when so much effort is spent on

trivial details, which do not push the job but cause unnecessary commotion around it.

The invisible costs of mechanization

Once a machine is brought, not only is its capital cost fully incurred, but there are hourly charges on account of interest and depreciation. Its life depends on the manner in which it is used. Even want of use can ruin it as the parts rust and deteriorate under exposure and weather. This aspect brings a new feature in the pattern of economy which governs engineering projects of today. The utilization factor of machinery controls the economy much more than any small aberration from the set rules of audit. Even as a businessman knows how to act with speed and prompt attention and decision in the case of a crisis in prices or safety of stock, so also must engineers be able to act without delay and hesitation, when the interests of the Project requires them to rise to the occasion. In such a contingency, finance should have a positive and not a negative approach.

Evolution of the new method of Financial control

The progress of the Bhakra Nangal Project has depended so much on the procedures of financial sanctions and checks, that the Bhakra Nangal story will be quite incomplete without a record of the sucessive evolutionary steps which were found necessary. Looking back over the last 10 years of the Project history, one might say that the biggest hurdle, next to personnel, in the speedy execution of the Project, has been the unhelpful rules and regulations of finance and audit.

One thing needs to be made clear. There can possibly be no objection to obeying the vital rules regarding budget, accounting of expenditure and following of those checks and regulations of finance and audit, which insure the health of the Project and bring offenders and suspects quickly to book. The tragedy is that even after the man-at-the-helm has been given the word "go", he is hedged in by so many formalities and so much red tape, that he cannot give orders and decisions which are essential for the uninterrrupted execution and complete implementation of the Project.

Early Codes for Projects

The Public Work Account Code was originally made fifty years ago. It was an admirable guide for the financial safety of the Projects under conditions prevailing at that time. The British Administrator, Auditor General and Engineer spoke with one language —distrust of the native personnel. The nature and size of works were also such that the observance of the hard and fast lines of the rules did not impede progress. And whenever any matter of policy was involved, it was seldom difficult for the British engineer to obtain full clearance all along the line to push on with his programme. Full delegations were usually available down to Executive Engineer level in the matter of purchases, rates and contracts, so the work went on unimpeded so far as financial checks were concerned. The responsibility for preparation of the Project, and the main Project Estimate was definitely of the engineer and this was usually discharged in a thorough and unambiguous manner. But once the scheme had been accepted and sanctioned in its broad details, he was not required continually to report back regarding every change of design or modification of construction methods or programmes.

Undue Restrictions

Examples of the unbusinesslike rules now prevailing in Public Works Departments are numerous and can be multiplied. There are considerable restrictions on the purchase of motor vehicles, bicycles, typewriters and stationery. In the matter of telephones the delegations are so restrictive that a Government Office handling works worth crores of rupees annually is without a telephone whereas an officer in several other departments with 1/10th of the responsibility has the facility of a telephone. This also contrasts with other countries particularly U.S.A. where most of the discussions and decisions are finalized over the phone. The Bhakra Nangal Project have taken huge strides forward in this matter, but the birth-pangs have been too painful and cumbersome and a lot of ground still remains to be covered.

There is urgent necessity for revision of the code and for bringing it into line with modern requirements. Vouchers and receipts have to be produced for a check, recheck and countercheck for petty amount. The paper work involved is quite incommensurate with the advantage gained or the authentication of expenditures. This can as well be secured by a simple certificate by an official at approriate level. It should be left to his discretion to verify that there has been no defalcation or falsification of accounts.

Adequate Delegations

In the case of the Bhakra Nangal Project the delegation of Powers of Chief Engineers and lower down were increased, but these were not made comprehensive enough to enable an uninterrupted prosecution of the work. The principle has, however, been recognized and the Engineers Seminars have laid stress on further improvements in the procedure. One big hurdle in the evolution is the lack of understanding of engineering details by the officials of the audit and accounts departments. Steps have been suggested for the training of such personnel, so that by their better acquaintance with the essential details, they may understand the necessity for modifications and changes and recognize their inevitability rather than question the motive or propriety of the changes.

So that this may not be a one-sided picture, we have to recognize the overall necessity and importance of harnessing and regulating expenditures. Any cases of wastage or defalcation or misappropriation must be detected and controlled in time, if the "health and sanitation rules" for honesty and economy are to be enforced. For this purpose there should be proper proforma in which definite certificates must be obtained from the engineer-in-charge at all levels that the work is proceeding within the estimated targets of rates and costs. Wherever there is doubt in this regard, executive action (not audit action alone) must be taken to review the position and adjudicate on the propriety of expenditure and costs. In this manner, real control will be possible and the necessary disciplinary measures taken in time.

Too many clearances

The principles to be followed would obviate the necessity of too many clearances. They will confer more final powers on the engineers on the spot, so

Board of Consultants visit the Bhakra Dam site in October, 1952. *L* **to** *R:* **Khungar, Nickel, Savage, Khosla, Banks, Meclellan, Hammand, Steel, Johnson, Rawhauser, Handa, Pathak, Gupta, Hazra, Bhatnagar, Barkat Ram, Chadha.**

that the works may not have to be kept suspended or slowed down for want of sanction which are always pending. Instead of finance and audit acting as brakes at every step, they will also require display of initiative and businesslike foresight as co-sharers of responsbility with the executive. Not only acts of commission, but acts of omission are also harmful when achievement has to be secured at the highest level of output and quantity with the least expenditure of time and money.

Avoidable waste of energy

Above all, it has to be ensured that no process involves a disproportionate expenditure of time and money as compared to the results secured. At present too much energy is taken away by the correspondence over routine matter. It is better for all concerned that the codes are amended to cover the precautions necessary for day-to-day working, without damping initiative for courageous action, necessary for attaining high standards in engineering design and execution, which alone are the true criteria for high standard work in the last analysis.

Absured and obsolete financial rules

The time has now come when obsolete and antiquated rules should be abolished and replaced by their modern and practical counterparts. We must go back to first principles and not forget the context in which the previous rules were framed. The powers which are vested in finance and audit need to be relaxed where they are at the moment a hinderance in the path of progress. And they need to be tightened further where there are loopholes due to which embezzlement and misappropriation can take place. The vital principle to understand is that it is only through the planning and construction of new projects that more production can be ensured. And until there is greater production, the poverty of the country will not be banished. The finance and audit wings of the national forces, have to play a dual role. Their first function is to foster progress and vigorous prosecution of projects. Their second and equally important function is to exercise the role of the watch-dog without fear or favour. A healthy balance in the two roles is required and all concerned should cooperate to share the joint responsibility of the nation's development programmes.

Methods of Control

The present method of financial controls is more of a post-mortem operation rather than a healthy check that can be applied before and not after the mishap. There is any amount of accounting and auditing and re-accounting and re-auditing, but the hand that errs cannot be guided to prevent the error. Similarly there is too great a supression of the initiative with the frequent and multiple clearances that have to be sought and awaited from the finance department. Obviously there is a lack of fruitful coordination and too much importance is given to routine rather than intelligent research.

Trust and Delegation

There is obviously a need for increased trust and delegation. And the checks executed must be rigorous and unsparing although they may be less cumbersome and they need not be applied as frequently as is done now. An undertaking might well be obtained for the Project authorities themselves as to whether in their own assessment they are getting the full value value of every Rupee spent in terms of quality and progress. This statement, supported by approximate figures of achievement, expenditure and liabilities will be better than the dozens of lower level checks which are instituted by unimaginative and inexperienced accounts officers. In fact the audit department ought to be made co-responsible for the progress of the job. In their manner, their criticism will differentiate between the trivial and the vital and by putting their searchlight on important matters, they will be able to help the job and yet contribute to all the laws of "health and sanitation".

Panel of Senior Engineers

The time has come when the State and Central Governments should have recourse to a standing panel of senior (including retired) engineers, who should pronounce on the suitability and propriety of the methods and provisions included in a project. By so doing the major pitfalls will come to notice in good time to effect prevention and remedy while the things are not far advanced and much time and money have not been irrevocably lost.

Importance of Incentive

It would be indeed a defect rather than victory of incentive and enthusiasm on the part of engineers if integrity and worth is rewarded not by appreciation but by fault-finding and calumny. Let the auditors and the public accounts committees haul up the diminutive miniority of wrong-doers, rather than damp and slow down the ardour of honest worker who is a believer in trusting and being trusted. The principal hurdle in the way of quicker advancement in Projects is lack of trust rather than lack of finance and personnel.

Defects in old system

Several reasons have been already given to show why the Bhakra Nangal Project could not be modelled on the pattern of Barrage projects. It will perhaps be well to expand on some of the basic aspects to bring out why a change-over was unavoidable. One has only to go back to the evolution of the P.W.D. system of working to appreciate why the old methods could not fill the bill.

Inadequacy

The foremost reason is the revolutionary changes that have crept into the methods of construction both in speed and technique. The proforma devised for progress reporting, labour attendance and payment and working out of unit rates and cost data have all become more or less obsolete. It is an admitted fact that they have served the purpose fairly well for over-a-century, but our adherence to old traditions should not take us to the extreme of blindly carrying on what has ceased to be applicable. On the contrary, we should overselves discard the outmoded codes, and make new rules to suit the more dynamic and mechanized processes of today.

Progressive outlook essential

After all engineering is founded on discovering new methods for meeting our material requirements by increasing production and reducing labour and material costs. This urge for improving on our own standards is the real incentive to all engineering endeavour. And it must be reflected in all the corrected processes, whether they be of planning, designing, execution or financial control. Hence it should be taken as an axiomatic truth that the form is not so important as the substance. This fact has come to notice in the Bhakra Nangal project more than in smaller undertakings. And after a great deal of experimentation and struggle certain procedures have been stream-lined and simplified, although there is still a great deal of red-tape and form, which needs to be eliminated or modernized.

Too perfect and therefore imperfect

It is not unusual for any organization to frame a set of rules to circumscribe and regulate the working of its various components. The process is initiated by some outstanding member of the profession who can see much farther ahead than his average compeers. He frames the law, as it were, followed by rules which govern the application of the law. The same may be said of the Codes of Public Works Management and Public Works Accounts. For the type and size of works which fall in the same category as those for which these codes were framed, there is no trouble. But the moment we want to apply the same procedures to modern methods and techniques of construction, we have to accept defeat and frustration besides a lot of bad blood that inevitably ensues between the zealous protagonists of the old school and the more progressive sections, who clamour for a change of outlook. The remedy generally lies in an objective appraisement with an emphasis on change where it is so required.

Not suited to mechanized working

In particular, we have to mark on to a new outlook where civil works are carried out by the use of a large proportion of machinery as compared to hand labour methods. In this case the cost of the machines in Capital investment followed by the heavy charges of interest and depreciation make it essential that the old time rules be revised and changed so as to bring in uppermost an element of urgency and despatch in the entire process. The extra cost of installing a telephone system on a mechanized job will be more than offset by the savings in man-hours and machine-hours. Similarly some of the spare parts may have to be procured by the quickest transport, even by air. Such contingencies must be viewed with constructive imagination, and it should be made a part of the duties of management to anticipate the necessity of such changes rather than adopt an obstructive or unresponsive attitude.

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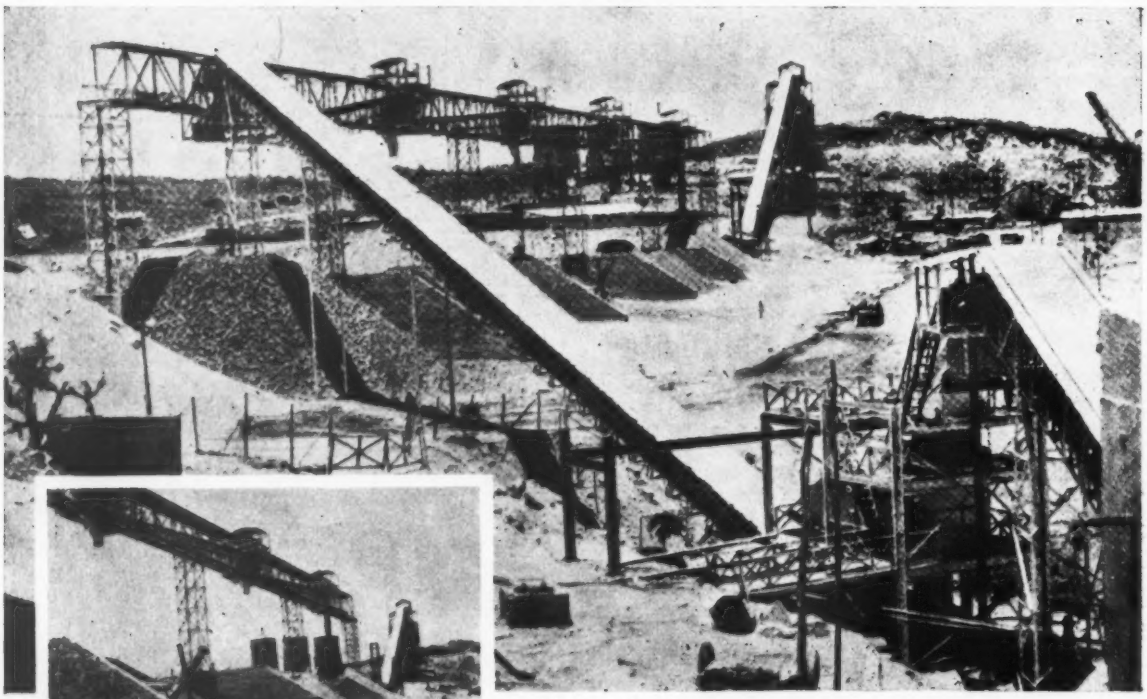

▲ At 200-tons per hour, aggregate for damming the Barakar River moves by S-A Conveyor from the secondary crusher (right) foreground) to a battery of S-A screens over storage bins.

◀ A conveyor belt under these storage bins reclaims aggregate and moves it to the concrete batching plant as needed. Underground S-A conveyor is 720-feet long and handles 300-tons per hour.

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Mechanization

The history of the introduction of machinery in construction work as against manual and animal labour is briefly presented, its rates and costs are discussed. The problem of men without machines or of machines without men is posed. The operating cost of equipment and its maintenance are discussed. The various schools of thought in this regard are taken cognisance of.

The entire field of River Valley Projects is now influenced by the degree of mechanization that is introduced in the construction processes. There was a time when labour was so cheap that targets had very little significance. Whether a project was completed in 5 years or 10 years, the cost remained much the same. Also the object in the formulation and completion of projects was generally based on political considerations or famine relief purposes. There was no attempt at harnessing the complete resources of a river basin. Electric power was also not allowed to develop at too fast a rate because the country was to be kept under the yoke of foreign rule through a continued agricultural economy which would keep the country just above the starvation level. It was argued by the foreign rulers that such is the fate of this country because of the uncertain nature of the monsoons—destiny over which human endeavour could have little control.

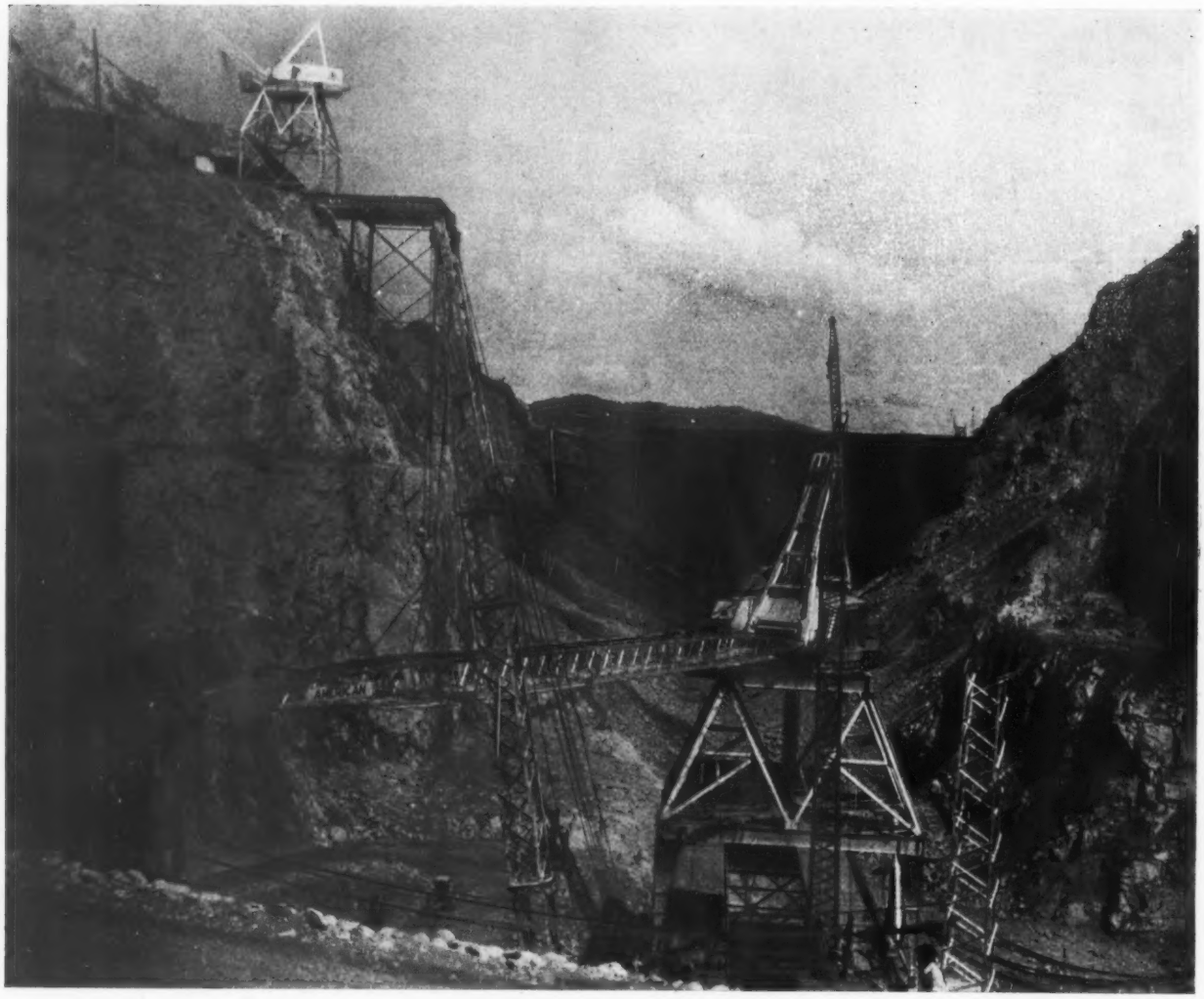
This picture could not however be maintained for long. Indians who visited abroad during last 50 years always came back with the impression that it was the extensive use of science and machinery that has made the Western Nations rich. They had a burning desire to introduce the same techniques in our own projects, but here again the limitations of the British rule made things difficult. The ex-Rulers were happy only if machinery was not used at all or if the machinery used was of a type and size which was manufactured in the United Kingdom and which could be exported from there to India under some sort of Imperial preferences. The barriers of colonial rule handicapped the development of this country. The abolition of these barriers since the date of the partition has demonstrated how badly our wings were clipped. In this short interval of 8 years India has forged ahead largely on the strength of machines. Those jobs which were previously done in years are now being completed in months and weeks. The budget for the river valley projects in the last 5 years has been more than the entire amount that was spent in the previous one hundred years. Also the development is countrywide. It has gone beyond provincial boundaries and other local limitations. There has no doubt been some controversy as to whether the machines should be introduced on a large scale or not for the execution of the river valley projects but it is now conceded on all hands that the best solution is neither the one extreme nor the other. A compromise must be made to find an optimum combination of machines and manual and animal labour of various types according to the nature, peculiar difficulties and economics of the various components of a project.

The policy of the Union and the State Governments and also of private construction companies has therefore been in favour of such a combination. A great success has already been achieved in the major projects of the country—Bhakra Nangal, D.V.C., Hirakud and other projects. It is, however, of vital importance that wholesale imitation of foreign countries be not made. The economy of each country has its own characteristics and blind imitation generally leads to trouble. It is therefore of utmost importance that those responsible for the design and execution of works, make a special study of the implication of mechanizing the various operations. This aspect is developed further in this article.

Achievements

The fruits of mechanization have been copious and impressive. Already the tempo of progress has beaten the most sanguine expectations of the planners. The pessimists who were either wholly against mechanization or who predicted its failure have been proved wrong. As in the West, so in the East, the mastery of men over nature through scientific knowledge and its application to machines, has been the underlying theme of the present renaissance in India. We are already self-sufficient in food and the 2nd Five Year Plan bids every hope of a phenomenal increase in our industrial and employment potential. The standard of living is expected to go up 5 percent per year. This has been made possible only by mechanization of our construction methods.

Now we can undertake river works or roads or railroads or housing schemes of large magnitude with quick targets. Rock excavation with shovels and Euclids has made it possible to excavate some 10 million cubic yards of rock and overburden at Bhakra Dam site within two working seasons. Similarly colossal quantities have been handled on the Nangal and Bhakra canals in cuttings and fillings with the help of draglines, scrapers and bull-dozers. New records have been created by virtue of which we have ceased to wonder at some of the classical achievements like the Upper Ganges Canal and the Upper Jhelum Canal. These were indeed great jobs as long as machines did not come on the scene, but now



Concreting of Dam under progress

they have dwarfed into the common range, because machines give speedier, bigger and even cheaper results.

But this phase of our work is only the first chapter of a historic period in which most of the drama has still to be enacted. The advantage of the research and experience of other countries is available to India, but that alone is not enough. The path of least resistance will be that of limitation. There are enough salesmen and agency holders of Western firms who are advocating a wholesale adoption of Western equipment with little or no variation. But the best results do not lie that way. Like other processes, mechanization of construction requires the genius of India to come into play. The economic pattern of capital, material and labour costs as prevalent in this country should be the governing criterion in our choice of equipment. For this ideal, we have to work our own solutions. Not only imitation, but improvisation and invention have to be our mainstay for proper development.

History of Evolution

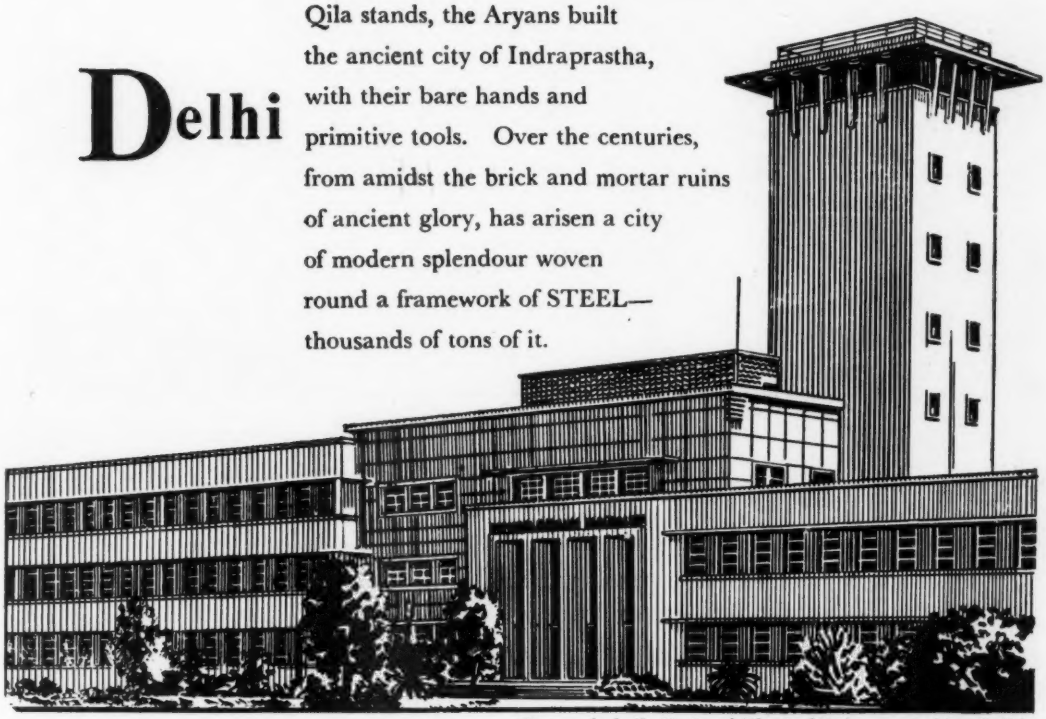
One has not to go very far back to trace out the beginnings of mechanization in River Valley Projects. The canals constructed during the early British days (1850-1890) were largely the product of manual and animal labour. Men and women with little baskets over their heads made the huge embankments, stone spurs and heavy cuttings. Donkeys, camels and elephants carried loads and also provided the necessary compactive effort for reaches of high filling. Although the techniques had not been developed to the present scientific status, the thumb rules and empirical knowledge of the British and Indian pioneers were cute and remarkable. The resulting works have, therefore, been successful examples of stability, and durability. And the financial yardsticks of the time were more than satisfied, as irrigation works constructed in the last one hundred years have been remunerative, beyond dispute, to the State as well as the people.

The labour forces which achieved these colossal

" Where now the city stands,
there was once naught but the city's site." OVID

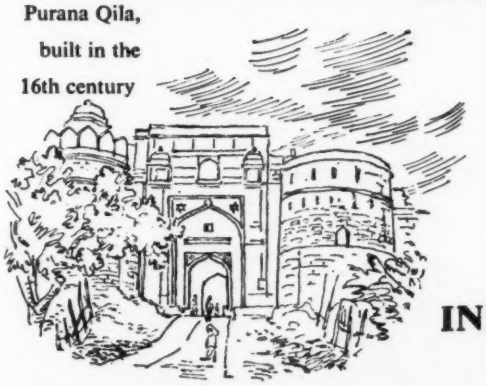
Delhi

It was eight centuries before the birth of Rome. On the banks of the Jamuna, where the Purana Qila stands, the Aryans built the ancient city of Indraprastha, with their bare hands and primitive tools. Over the centuries, from amidst the brick and mortar ruins of ancient glory, has arisen a city of modern splendour woven round a framework of STEEL—thousands of tons of it.



The newly built National Physical Laboratory, New Delhi

Purana Qila, built in the 16th century



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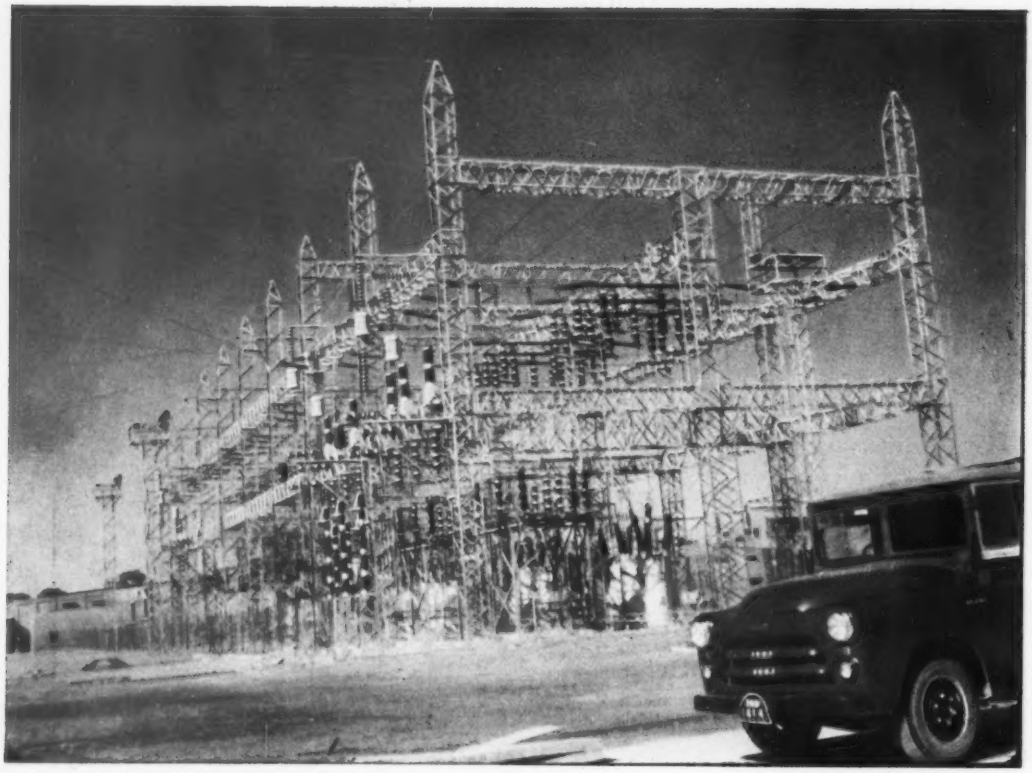
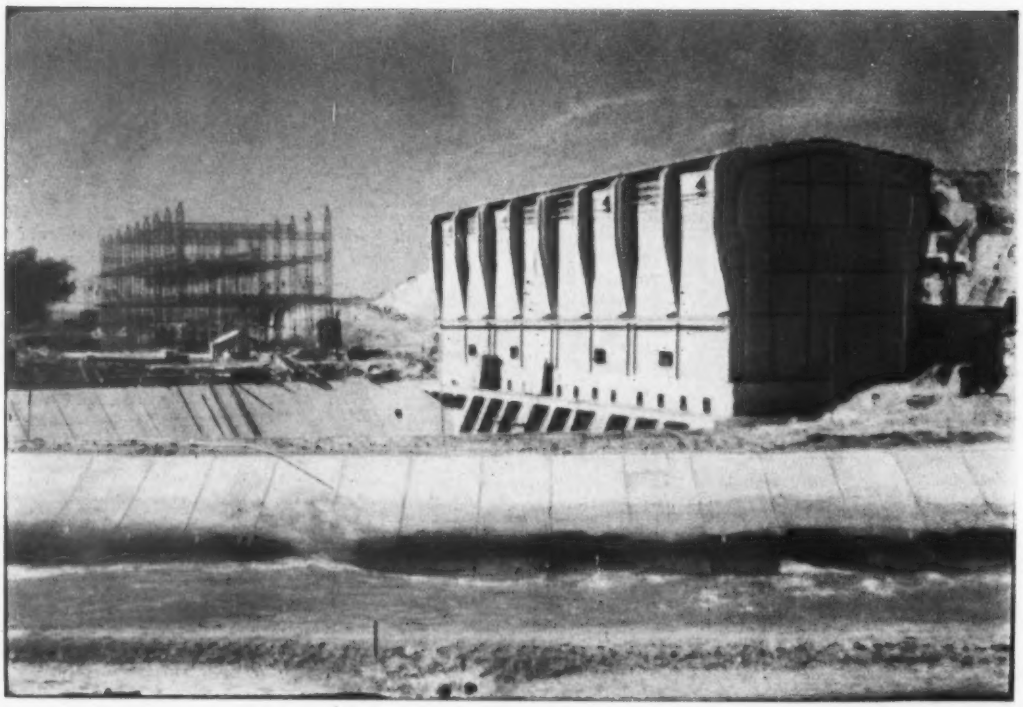
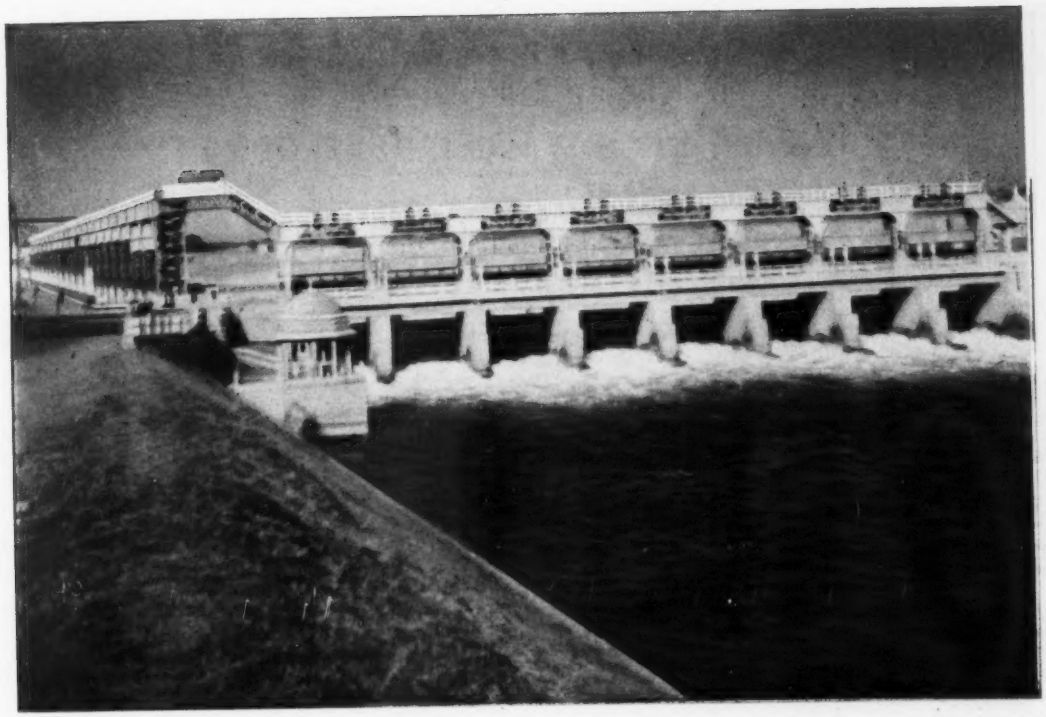


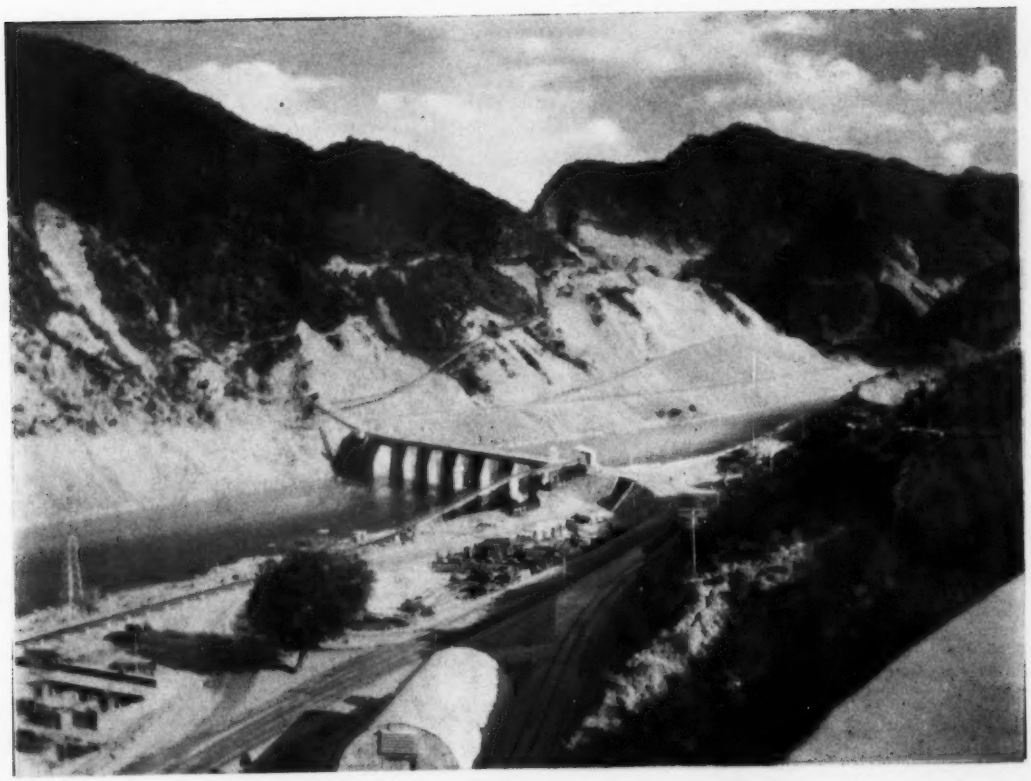
Ganguwal Switchyard



Kotla Power House & Switchyard under Construction



Nangal Dam & Head Works



Downstream of Bhakra Dam

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SPECIAL NUMBER
ON
HIRAKUD DAM PROJECT

On the occasion of the inauguration of the Dam by Sri Jawaharlal Nehru at Hirakud in November 1956 next. The chief contributions of the Number together with their authors are listed below :-

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by A. R. Chellani, Superintending Engineer, in Charge of the Main Dam, and K. R. Chandrasekharan, Assistant Executive Engineer.

POWER GENERATION AT HIRAKUD
by N. Dharmarajan, Superintending Engineer in Charge of the Power System.

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Shovel in operation at Bhakra

works were derived from particular regions and certain tribes excelled in this art. The Pathan donkey with his greater counterpart, the Pathan donkey driver, had established their reputation for earthwork jobs involving wet earthwork and long leads. It was not only the donkeys but the drivers and their long sticks that produced the big daily outturn. And the Pathan fed his donkey liberally—much like his own standard of rations. At the commencement of each season, the upcountry contractors used to buy donkeys or collect donkey owners, to make a formidable team of 1000 or 2000 donkeys to engage in the operation of making ringbunds and cofferdams for the constructions of barrages and weirs. In the Punjab, the successive construction of the triple canal system in 1912, followed by the Sutlej Valley canals in 1925 and then by the Haveli in 1937, the Thal in 1945, provided an uninterrupted chain of works which maintained the grand prospect of additional arid areas brought under irrigation and modern agriculture. The desert of Northwest India thus became the granary and the source of huge quantities of cotton. Both commodities were needed by England to expand her own economy of industrial exports. India fed Britain with all the food and also furnished cotton for the textile magnets of Liverpool and Manchester to send cloth for her undernourished, semi-naked millions.

During the two world wars, Indian soldiers went to foreign lands on behalf of Britain and saw great machines which the Western countries were using for the basic operations of earthwork, transportation and concrete manufacture. The British had been clever in selling their railroad products to India. This popularized the use of steamlocos and railway trucks and narrow gauge tip wagons on Indian projects. Portable steam engines used at Marala Headworks in 1908 were still living in old age, as recently as 1945, when certain remodelling schemes were executed on the Western Yamuna Headworks and canals. The Bhakra Nangal Project appeared on the scene when the country was gripped with the fever of partition. The Pathan Labour force employed at the Nangal Headworks made preference to migrate to West Punjab and the work came to a standstill. It was at this time that the Diesel operated dumper succeeded the Pathan donkey. In the course of a few months, the scene was entirely transformed and one could see lacs of cubic feet of earthwork and gravel being hauled out of the Nangal dam pit by 40 one cubic yard dumpers. The drivers sitting at the wheel acquired the necessary skill in weeks rather than months and a most orderly chain of excavation and dumping operations emerged from the serious crisis which threatened complete stoppage of work on the Nangal Dam and the Nangal Hydel Canal.

This was the beginning of a most eventful chapter of mechanization in the construction operations in River Valley Projects. The step once taken could never be reversed. In fact other machines appeared rapidly on the scene. Crushing of aggregate, batching plants, automatic mixers, transport and placement of concrete with improvised narrowgauge wagons and air operated concrete buckets hoisted by some of the old cranes, created a picturesque and impressive

Drilling Operations

scene, which was to be the precursor of the big Bhakra Dam set up—which project, as indicated later, is the biggest job of its kind, under construction anywhere in the world at this time.

Schedules

At this stage we must take due recognition of the fact that mechanized construction requires schedules for progress and target dates to be framed with much greater imagination and foresight. On a construction job where machinery worth crores of rupees is kept and maintained with all the attendent crews, it becomes important that each unit is suitably and adequately employed. The charge on account of interest alone is of the order of rupees one lac per day. This is usually doubled when depreciation is taken into account. Hence the importance of each unit going to work for the maximum amount of time each day cannot be over-emphasized. There is no doubt that the charges are imperceptible and gradual but they are reflected in the costs of the various operations. To keep the unit costs down it becomes imperative to watch that the plant is deployed methodically so as to give maximum outturn. Enough working space has to be visualized and provided, as plant can only give economical operation if there is ample room for its unhampered working. The rate of sickness in plant has to be kept down to the very minimum. Adequate facilities have to be created for repairs and spare services. All this information is best maintained in the form of schedules—an American term for tabulated statements or inventories. It has now become increasingly important that all planning whether for design and construction is reduced to schedule form which gives a visual picture easy to review from time to time.

It appears necessary to remark here that the habit of drawing up schedules is not as much in vogue in the organizations of this country as it should be. The idea of schedules is not altogether new. In fact many organizations have used schedules for many years past but it ought to be admitted that the importance of such procedure is not realized to the same degree in every tier of the oraganization. In the last analysis, the economy of a project is a direct function of the time which is spent in its planning, design and completion. Maximum outturn within minimum time whether for man power or machines is the unfailing formula which should serve as an ever present yardstick to measure efficiency.

Rates & Costs

With the use of machines for the construction of a project we enter an altogether new phase regarding the rates and costs for the various items of work. The present ideas of many plant users are comparatively under-developed as the considerations that enter into the analysis are varied and sometime imperceptible. It will do well if we review the question under some broad features.

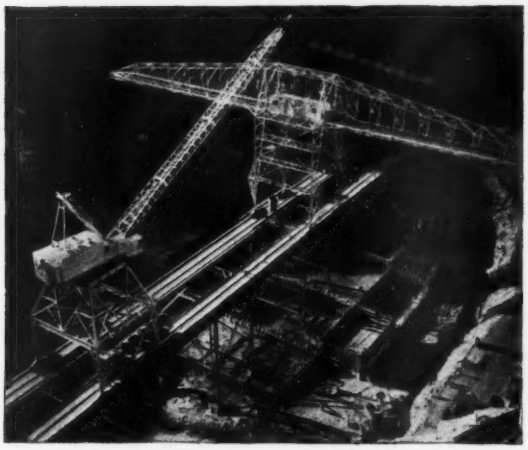
The most invisible costs are depreciation and interest whether or not the plant is used. It was usual to take the life of a piece of equipment as 16 years in the early days of irrigation practice in this country. This yardstick was certainly not very scientific as it did not take into account the number of hours for which the plant was used or the type of service that was obtained out of it. It is only recently that an attempt had been made at standardizing the life expectation of equipment in the recent meetings of the Engineer's Seminar set up by the Irrigation and Power Ministry of the Union Government.

The hand books supplied by foreign manufacturers are fairly reliable guides but the job-factor and the management factor are two vital considerations which govern the figure that we applied to a particular job.

As regards interest, the charges are easily determinable. However, attempts are made sometimes in putting up an analysis of rates from which the item of interest is omitted. This is definitely an under-representation of the true state of things and sanctioning authorities must carefully scrutinise that proper provision is made for this item in analysis of rates comparing the unit cost of working with machinery to hand labour costs.

A major consideration which should govern the

Diamond drilling in operation



Two big Cranes hovering over the gorge area for placement of concrete

analysis of rates based on the working of any item of equipment, is whether that piece of equipment is to be used continuously for its entire life or not. This is generally not possible on any single job but can certainly be made possible if the item of equipment is transferred from one project to another where its utilization is efficient and economical. This consideration makes it incumbent on the planners of projects to so arrange that there is continuous work for at least ten to fifteen years. This is an important element in planning and its achievement has been already exemplified in the case of the Bureau of Reclamation, T.V.A., Bhakra Nangal Project, D.V.C. etc. It is highly important that the next job to which the plant is to be transferred is definitely ear-marked and not left in the air. The cost of projects can be considerably brought down in this manner because the first cost of equipment is very high fraction of the total cost. Thus in the case of the Bhakra Dam, the construction plant is of the order of rupees ten crores in total cost for a job costing about 65 crores in all (figures approximate).

In order to make the maximum use of equipment and to reduce costs to the minimum, the management have to realize that losses start from the very hour when a machine goes sick or meets with an accident or is otherwise out of commission. If it needs spares and the usual routine of placing orders for spares after obtaining quotatoins etc. is followed, a big loss is almost inevitable. It has been the painful experience of the authorities in charge of construction that equipment has remained idle for weeks and months for sometime due to the non-arrangement of spare parts or the requisite overhauling crew. Imagine a piece of equipment breaking down in a wilderness on the site of the work of a Canal construction which is far removed from a railway station, workshop or other facilities. The details of the accident and the replacement parts needs to be worked out without any loss of time. In most cases, there is no telephone connection available from the site of work to the base at headquarters. The report usually comes by dak or by a special messenger who is to trudge it on foot or cycle. Many valuable hours (nay days or weeks) are lost. All this means waste of money and higher unit cost. When we decide to mechanise the construction processes of a certain project we should also take necessary steps to establish quick means of communication and expeditious handling of the situation. At the moment the position is anomalous as machines worth lacs of rupees have to be run by organizations, who need clearance of two finance departments and two governments before they can get their proposals through. The removal of this bottleneck is one of the most important improvements that needs to be brought into our present system of public works procedure.

In order to keep the costs of overhaul and repairs down to the minimum, the establishment of workshop facilities in the field and at the base is essential. These are generally not visualized early enough with the result that valuable time and money are lost. It is better to delay the commissioning of a plant rather than to risk it with inadequate arrangements for repairs and service. It is important that civil engineers in charge of operations are also trained in the technique of maintaining equipment and the realization is brought home to them that mechanizing operations need the same attention and care as are exercised by a unit of the army engaged in operations. The attitude of complacence or wait-and-see is to be discouraged outright.

The disposal of plant and equipment after use is also a most important matter. Nothing can injure the plant more than its marking time for the next job. In such a situation no party is interested in its preservation or maintenance. This is particularly true of government works where at the tail end of the construction the mechanical staff is suddenly reduced to such small proportions that they are unable to do justice to this aspect of the plant. It should be the responsibility of the division that has used the equipment to recondition it to a stage where it can be declared as complete and serviceable. The price of overhauls etc. should better be added to the depreciated book value and obtained out of the purchaser. If plant is allowed to fall into dis-repair and the wind and weather are allowed to play havoc on all the intricate mechanism, the overhauling cost becomes heavy. This form of neglect constitutes a big national waste and must be condemned from the highest quarter. This is particularly necessary on account of the general shortage of equipment and the relatively high costs for wholesale replacements.

A drilling machine in operation

A team of Euclid Shovels and a Bulldozer

The time has now come when standards can be laid down for the different items of equipment by classifying them into categories by sizes and types of service. Some of the essential information is included in appendices.

Manual versus Mechanized construction

The era of controversy as to whether or not we should mechanize our construction procedure is now very nearly over. For Engineers in India to take the attitude of anti-mechanization in this year of the 20th century would be an extremely retrograde step. How are we in that case to overcome the hurdles of the comparatively difficult projects involving tunnels and high dams? In fact India should now be in the vanguard of the processes of mechanization and the initial handicap of the delay already occasioned should be made up.

Even the most ardent advocates of hand labour methods will admit that works involving long leads, excavations below ground water level and closure operations in river diversions and coffer dams were by their very nature, not capable of being executed with the certainty and economy that machines ensure. Modern shovels, draglines, dumpers, scrapers and bull-dozers are, as it were, the giants of power, which act like the genii of Alladdin's lamp. Hence any job of considerable size, which can utilize machines of the above category can only do so to inefficiency and waste.

The important factors which need to be kept prominently in view to ensure the success of the job when it is mechanized, relate to the selection, repairs and maintenance and correct operation of the plant. The largest of machines need utmost care for their lubrication and maintenance. These must be ensured at a standard which is beyond all doubts. There must be periodic and automatic checks and the operating and maintenance crews attend to the precautions needed for the best performance of the machines.

Even when we talk of manual methods now, the advantage of proper hand-tools must be envisaged. It is a well known fact that a labourer can put out twice the amount of work with a wheel barrow as with the basket. This illustrates how important it is to equip the manual labour with proper tools. Between complete mechanization and no mechanization, there is a large margin for improvement of the hand tools. It may be said that the output from labour can be increased by a substantial amount if the employer devotes his attention to giving them modern and efficient tools.

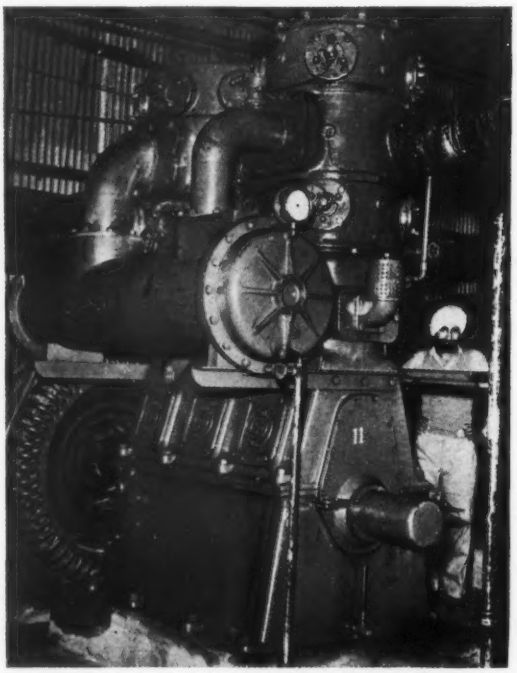
Men without Machines

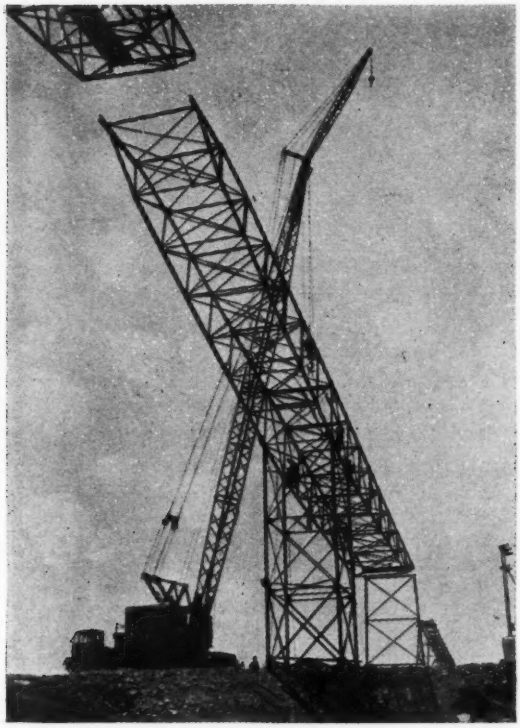
It is high time that we in India recognized that our progress is never going to catch up with the standards of advanced countries unless we make the fullest use of scientific inventions and techniques. This applies to all fields of development and particularly to the construction of modern dams and powerhouses in river valley development schemes. The achievement of the targets of quality and uniformity without the help of machines is as impossible as the prospect of men flying without an aeroplane or producing electric power without a generating plant.

The constructive approach to the question of mechanization is therefore not one in which there may be any two opinions as to whether or not we should mechanize, but only how best and how soon we can mechanize. The question involves economic analysis after taking into account the limitations of resources and time. It is also important that the right type of machine and the right size be procured for a specific job. There are so many hurdles and pitfalls in this process that utmost attention and care must be exercised before undertaking a large scale expenditure in the purchase of the equipment.

The great disparity that exist in the outturn and cost of work from men unassisted by machines, compared with a set-up where the necessary quota of modern equipment is also harnessed makes it patent that all works of magnitude should henceforth be based on the requisite degree of mechanization. The prospect of achieving the targets of the 2nd Five

Inside view of the Compressor house





Erecting the Double Cantilever Crane

Year Plan are linked inextricably with the degree of mechanization which we must introduce in all phases of our development works.

Machines without Men

In our enthusiasm for mechanization, we must not over-shoot the mark and resort to blind imitation of the Western countries where the economy is altogether different. To try to convert each construction process into 100% automatic working is clearly not suited to the conditions of our country. Where the wages of labour are so exorbitant that the elimination of every single operator means a great deal to the operational costs, it is worth while incurring huge expenditures in making the working automatic. But in the present state of things, where an operator in India can be got at wages which are 1/10th or 1/5th of the Western countries there is no justification for making the machines 100% automatic even if on a theoretical bosis it would be better to eliminate the human hand from some of the processes.

For the same reason, we have to beware of a situation where the mechanization process is carried to an unbalanced extreme. At the Ross Dam, in 1945, the winter witnessed a situation where the lack of 20 carpenters had brought the dam construction work to a standstill. There were machines worth 10 million dollars, installed in position but unable to help the works because the human element of a few carpenters could not be furnished or harnessed. Fortunately we in India, have a manpower resource which is abundant and unlikely to be pampered to the extent that they may be able to thwart the progress of a construction. But there is a definite signal for caution that the same unbalanced conditions do not beset our own projects.

Operating Costs of Equipment

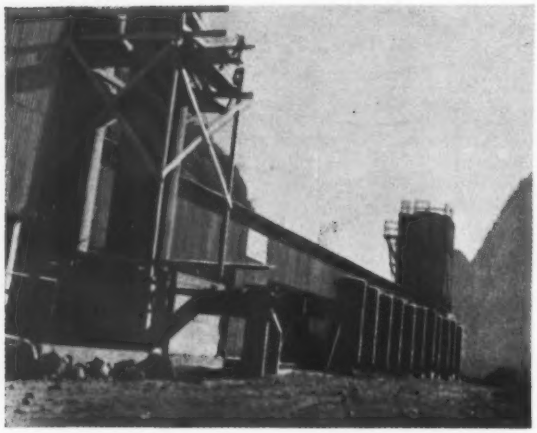
If the question of selection of equipment is settled, the costs of operation are the principal factor which will make the mechanization a success or failure. This aspect has been thoroughly (but after a long and painful process) brought out in the Bhakra Nangal Project experience. Once a machine goes to work, it is liable to get out of order at any time. Several things can happen to it ranging from an accident leading to complete destruction to a minor maladjustment in the carburettor, which would put it out of action. All the same the depreciation and interest costs keep on mounting and there is also the setting back of the construction schedule if the machine breaks down too frequently and remains under repairs and overhaul for too long a period. These factors govern the cost of operation vitally. In many cases they are over-riding causes of over expenditure.

A continuous source of inefficiency is that the machines get out of adjustment or there is lack of proper service and lubrication at due intervals. These can be remedied by the establishment of suitable workshops with a crew for servicing and check-ups. Again in the case of a big job like the Bhakra Dam, due precautions have been taken to maintain a base workshop, a field workshop and a number of small repair shops with a mobile plant for carrying out servicing and lubrication without moving the major items of equipment away from the site of work. These facilities have proved their utility and the expense with which they have been set up is commensurate with the size of the job. If anybody takes objection to such items of expenditure, he would not be realistic.

Policy of Overhauls

As sure as a machine is in good condition today, it will also be in a bad and worn out condition tomorrow. This fact has to be kept prominently in one's mind while dealing with mechanical equipment. It is on this basis that the entire range of equipment for the Bhakra Dam work has been purchased and put into service. An organization has been built up for the ready availability of spare parts or its earliest procurement so as to be on hand when needed in the overhauling of the machines. A stage comes when it is real waste to have a machine operate rather than

Trolley in the Grouting and Drainage Tunnel



Compress room-outside view

torn down for repairs or overhaul. At this stage, the decision should be taken in an objective and scientific manner and the machine should not be run if permanent deterioration has to be prevented. This policy can only be followed if there are enough machines at hand and the interest of the job permits the taking away of the worn out machines. A coordination of these two requirements becomes a day-to-day responsibility. In the organization created for supervision of the machanical units on the job, there must be discretion given to the men on the spot to act with courage and decisiveness in all contingencies. It is only with this proviso that the machines on a job will be maintained in a worthwhile condition and achieve those long range economies which eventually decide the financial success or failure of the venture.

List of Equipment

It is extremely helpful in the case of a big project to maintain an uptodate list of equipment together with necessary particulars. Such a list for each major job enables one to see it as it grows. Along with the lists there must be sufficient amount of details by which various machines and their spares can be indentified and orders for repairs and spares placed speedily with confidence.

Such lists of machines and their specifications and inventory of spare parts can be of great help in coordination between various centres of activity. On the T.V.A., there was a central department who were getting all information in this respect and keeping it uptodate. It is well to recognize the fact that there cannot be sufficient emphasis on this aspect if a job is to be really served efficiently by mechanized methods. In the last analysis efficiency is the result of experience gained in this field over similar projects. It is therefore, important that we should pay utmost attention to experience gained on other projects in this country. We should follow those rules and procedures which have been evolved on completed jobs and have been confirmed by good results. There is an awakening in this respect in all the States and the Centre. The Engineer's Seminars held at Nangal, Roorkee and Srinagar have covered useful ground.

Personnel: Critical Appraisement

The biggest hurdle in the proper upkeep of machines lies in personnel. If we look back over the few pages of history of construction in India, particularly in the government-owned departments, we will notice that the scales of salaries have been very low. The reason is not far to seek. Only very low class, unskilled or semi-skilled workmen were derived from Indian ranks. The skilled workers, mechanics, foremen etc. were foreigners who were imported on huge salaries. On account of the fact that suitable men from this country were not apprenticed to the foreign technicians, the exchange of knowledge and experience was badly retarded. As a result thereof, all the Graduate Engineers, (civil, mechanical or electrical), who were produced by the Universities of this country had no opportunity of rolling up their shirt sleeves and working with their hands or getting under the machines themselves. It has now been established and the fact is admitted on the Bhakra Dam organization that we need a better class of workers to act as Foremen or Master Mechanics for handling and operating expensive machines. Accordingly an incentive has been offered to the younger officers working on the Bhakra Dam that they would get an extra allowance of 1/3rd to 1/4th of their salary in case they operate the machines themselves for a period. This has been responded to enthusiastically and the results so far obtained are very promising.

Cost of Operation: Critical Apparaisement: Two schools of thought

A heated controversy has raged round the question of cost of construction by highly mechanized methods. The protagonists of one school have claimed that machines will reduce costs invariably. They have put up figures based on a rosy picture of trouble-free working with a small accident or sickness rate and a higher output per man hour. Such figures have soon been belied in actual working. The other school of thought goes to the opposite extreme and argues that the unit costs in this country will remain high under present working conditions because most of our construction machinery has to be imported and so is the case with most of the spare parts. The skill for overhauling or major repairs is also limited. The result is long periods of dis-use in which the interest and depreciation costs mount. Thus the overall rates tend to rise and grave disappointment has to be faced. The truth is really half-way.

"Pennywise Pound foolish"

The adage "pennywise pound foolish" applies with force to the principles of mechanization. The initial

Earthmoving equipment operating at site

A Shovel in operation at Bhakra

choice is most important because the saving of small sums in capital cost by choice of less-known makes is not wise. Similarly any stinting in the establishment of repair workshops is wrong policy. The approach of a novice is handicapped just by these features and he justifies it on the grounds of economy. The same applies to private organizations or Government departments. It is far better to plan on an integral basis of the overall costs of the entire range of essential facilities and then quote a figure. If machines are selected properly and the operation and repair services are wisely recruited and maintained, then we can depend on a low cost out-turn for the full life of the machines. That is the picture that one can confidently present and standby. As the science of mechanization advances we are bound to get into step with this tried process of evolution.

Difficult procedures streamlined

It must be admitted that there are certain elements which govern the costs intimately and yet these are beyond the control of a single authority or organization. These relate to the system of procurement and the channels which are set up for follow-up on purchase, inspection, shipment, and other multiple steps which must be completed before a job gets a certain article of equipment. Normally the channels of trade and private agencies are much faster than Government offices who are subject to red-tape in every phase. In the case of the Bhakra Nangal Project, the procedures have been considerably simplified. The necessary dollar exchange is placed at the disposal of the General Manager in advance. The choice of machinery is made with the help of the foreign specialists who have been engaged—mostly with the individual help of Mr. Harvey Slocum (designated as the Director of Construction and Plant Design and engaged on a contract for 10 years). The India Supply Mission invited tenders for the machines to be bought in the U.S.A. Inspection is arranged before the equipment is despatched, and payments are made promptly by the Technical Attache in Washington on special authorization in each case by the General Manger, Bhakra Dam. Delays that used to take place at Port of Eentry (Bombay or Calcutta) have been eliminated by the posting at Delhi and Bombay, of Transport and Liaison Officers who carry out a day-to-day followup in order to stream-line the various stages of clearance and despatch. The delays have been cut down to a degree which is a striking contrast to the original state of things when anything from 3 to 6 months was a rule for articles to reach from Bombay to Nangal. Now the period is 3 to 6 weeks and anything above this is an exception. Spare parts have at times been cleared from Bombay to Nangal within 2 to 3 days. The Bhakra Nangal Project have eventually worked upto the motto that delays mean tremendous costs—when you consider that non-receipt of essential materials at the site of work means a dislocation and getting back of the entire programme.

Telephone and Wireless Communication

Talking about the raised tempo in River Valley Projects, it is important to recognize the role of the wireless and telephone communication. It may be mentioned straightaway that although the Bhakra Nangal Project has been better served in this respect than other Projects, the gap has not been filled up as well as is really indicated in modern times. The advantage of quick communications is so great that all River Valley Project work centres should have it in as full measure as they have it in the U.S.A. Imagine the loss to the Project when equipment worth lacs of rupees goes out of service because of a breakdown or an accident and it takes weeks and months to have it repaired and brought back to working order. There are numerous stages—stripping down, examination, identification of spare parts needed procurement, overhauling, testing and commissioning. All these processes involve consultations and action at a far quicker pace than can be at all possible if we were to sit down and do it all in writing between a dozen offices situated at various headquarters.

This is one instance where telephone communication will pay hands down. The other needs are administrative when personal discussions have to precede decisions and action. In this category one must have also the "inter-com" system, which enables the various members of a large office to communicate with each other without having to leave their desks or drafting tables. This facility greatly reduces the waste of time which occurs when the merest superficial thought or suggestion has to be made on a file in red and blueblack manuscript or typed noting to enable any progress. In most cases the effort is quite disproportionate to the small results.

The above suggestions are not by any means new for private enterprise organizations. They are already well equipped. So are our armed forces. But for River Valley Projects, these improvements are so badly needed that some one has to present the picture as it really exists. It was all right in the pioneering days to depend on foot dak runners, camelmen or sowars to transmit messages, but now all are in the age of rapid progress and all anti-diluvian methods must be quickly replaced.

The big use that needs to be made of wireless communication is in the field of transmitting flood messages. Rain storms have been known to occur in the hills of the Punjab, which flooded places like Rupar and Ferozepur (100 to 200 miles below the storm affected catchment) overnight and before the warning signals could be put through. Telegraph, telephone and rail road communications usually fail at such times and considerable saving of life and property can be effected if the alert can be sounded a few hours earlier. Our raingauge stations and discharge sites on rivers must be equipped with wireless transmitters, so that we can protect ourselves more speedily against the incoming calamity.

At Bhakra, where the Sutlej has cut deep gorges in the mountains and strewn its banks with boulders, an endless conveyor belt carries these aggregates to the location of the dam. The conveyor system, the longest in India, is operated with push-button ease. The belt was made by Dunlop in India.

moving mountains by push-button conveyor belts

Dunlop conveyor belts, made to B.S.S. at Sahaganj, are superior :

★ *Tailor-made for specific service conditions.*
★ *Spliced at site by a Mobile Splicing team.*
★ *Tested rigorously to ensure world-famous Dunlop quality.*

DUNLOP

Dunlop conveyor belting at the Bhakra Nangal Dam.

DRAC-31

Construction Features

The Bhakra Dam Project being a unique one to be attempted in this country, several unique features in its construction have been experienced. This article considers some of them including such items as manufacture of aggregates and its transportation by belt conveyors, processing of the aggregates at Bhakra, the design mix for mass concrete, cooling of aggregates, handling of cement as well as its storage, construction plant layout, batching, mixing and placing of concrete, etc. This article also deals with the problem of mechanisation of construction, such as those of selection of equipment, its standardisation, etc. The list of principal equipments in use at Bhakra Dam is given.

The construction of the dam is being done departmentally by Indian personnel with the help of some foreign specialists. Modern construction methods and the best modern construction equipment are being used for speedy and efficient construction of the project.

(*i*) Present status of the project: (June, 1956) about 90% of the total of over five million of excavation completed.

(*ii*) Upstream and downstream cofferdams 200′ and 128′ above foundations completed and have been in service for 12 months with river flowing through the two 50 ft. dia. concrete lined tunnels.

(*iii*) Construction plant started pouring concrete on 17/11/55.

(*iv*) Concreting is in progress and will continue upto 1959.

Manufacture of aggregates

10 million tons of aggregates is to be quarried from Fatehwal and 2.5 million tons from Neilla.

Maximum quantity of processed aggregate required per month will be about 3,78,000 tons. For this about 5,84,000 tons of raw aggregate will have to be excavated.

Scalping units at Fatehwal and Neilla reject sizes over 7″ and under $\frac{3}{4}$″ respectively.

Raw aggregate is transported to the 25,000 tons main surge pile at Bhakra processing plant.

Transportation is done by means of a 36″ belt coveyor 9352 ft. long. This consists of seven flights which move at a speed of 450 ft per minute and transport over 900 tons per hour.

All multiple flight conveyors are electrically interlocked.

In case of stoppage or failure of any one flight, all the receiving flights halt automatically.

Telephones are provided at all halting points.

Processing Plant at Bhakra

This plant screens the aggregates received from Neilla, classifies sand and makes up any deficiencies by controlled crushing.

The processing plant consists of double-vibrating screens, Darco rake classifiers and sizers and cone crushers. Capacity of the plant is 850 tons per hour.

Design Mix

A typical design mix for mass concrete has the following proportions of various constituents and approximate quantities required to be produced per hour.

Size		*Tons per hour.*
7″—3″	905 lbs.	150
3″—1½″	686 lbs.	115
1½″—3/4″	604 lbs.	100
3/4″—No. 4 screen	550 lbs.	90
Sand	918 lbs.	150
TOTAL	3663 lbs.	615

The raw aggregate as it reaches Bhakra is well graded and does not require much crushing or washing, the only wastage being in the form of unwanted finer fractions of sand.

Cooling of aggregates

Concrete placement temperature at 65° F have been computed to be the best from the point of view of prevention of cracks. Without artificial precooling the placement temp. would be 85° F. The mean monthly air and water temperature attained at the sites ranges from 75.3° max. to 41.9° min. in December to 106.3° max. and 76.1° min. in June. The mean water temperature in the same period is 52.8° F and 65.6° F respectively.

About half a million c.yd concrete in foundation faults and spillway apron require to be specially precooled to temprature range 50° to 55° F.

The following alternatives were considered for attaining required temperatures.

(*a*) cooling coarse aggregate.

(*b*) cooling fine aggregate

(*c*) cooling cement

(*d*) chilling the mix water

(*e*) Replacing part of mix water by ice

If coarse aggregate is cooled to 38 degrees and chilled water is used for mixing, then we can attain a placing temperature of 65. The computations indicate that the temperature of the mixture would be only 60 degrees. Hence there is a reasonable margin.

Only coarse aggregate is cooled. Its weight is about 410 tons per hour. The cooling plant capacity has been fixed so that coarse aggregate may be cooled to a temperature of 38 degrees. The total refrigeration capacity including provision for losses and standby is of 1800 tons refrigeration.

Emulsion method is being adopted to cool the aggregate to 38 degrees. Various fractions of the coarse aggregate are emmersed in steel tanks through which chilled water is circulated. These tanks have been fabricated at the Bhakra Nangal workshops.

Handling of cement and its storage

Maximum quantity of concrete to be poured each month is 193,000 cubic yards. This requires about 870 tons of cement daily.

Cement comes from Surajpur at a rail distance of 118 miles. The transport is made in 120 twenty-ton size hopper bottom wagons. These have been specially manufactured to suit Indian Railway standards. The train cycle time is forty-eight hours. The hopper bottom wagons bring cement from the factory and discharge their contents into track hopper provided at the railway siding near the site of the dam.

Fuller Kinyon stationary pumps capable of pumping 100 tons of cement per hour, transfer the cement from the hoppers to any of the seven 840 tons cement storage steel silos located at EL. 1300. From the silos the cement is pumped to a service silo at EL. 1500 by means of two Fuller Kinyon pumps and from thereon to the Batching and Mixing Plant at the first stage through F.H Air slides and during the second stage by means of another Fuller Kinyon Pump.

Plant Layout at Dam

For placement of concrete, a two-stage system of trestles, with 2 double cantilever cranes (Hammerhead) and 3 whirly cranes operating on their tops has been selected. These are augmented by two stiffleg derricks and mobile cranes for placing concrete in zones which are not covered by the main system.

The double cantilevers have a total reach of 320 feet and are mounted on gantries which are 70′ high.

The whirlys are mounted on 60′ high gantries and have an operating radius of 160 ft. with a fully loaded 4 c.yd bucket.

In the 1st stage concrete upto elevation 1350, there will be 4 trestles. In the 2nd stage, there will be one more trestle for concreting above elevation 1350 to the top. The trestles will be installed by the use of the whirly cranes.

First stage arrangements

(*a*) Trestle No. 1, 400 ft. long to be erected parallel to the axis of the dam and 110′ upstream of it approximately. This will support tracks for whirly crane for concreting the upstream claytone plug etc.

(*b*) Trestle No. 2 is to be installed parallel to the axis of the dam and 135′ d/s of it. Its length is about 810′ and would support cantilever and whirly cranes for concreting main portion of dam, 1st stage.

(*c*) Trestle No. 3 will have a length of about 600 ft. and will be parallel to dam axis but 465′ d/s of it. Cantilever and whirly cranes for concreting the main dam and portion of the left power plant will operate from it.

(*d*) Trestle No. 4 has been installed normal to the axis of the dam with the centreline coinciding with that of the spillway and extending from a distance of 485′ to 1000′ measured from the axis and downstream of it. This supports a whirly crane for concreting the spillway apron and training walls and also a double cantilever crane for concreting.

Second Stage

(*a*) After completion of 1st stage of concreting, trestle No. 5, 110′ long would be erected. This would support cantilever crane for concreting in 2nd stage.

5,500 tons is the approximate weight of the steel involved in the trestles. These have been fabricated within the country by M/s Martin Burn. Certain steel parts of the trestles willl get permanently embedded in the concrete. Most of the steel from the 1st stage trestles will be reused in the second stage.

Batching and Mixing and Placing of Concrete

A batching and mixing plant with four mixers, each four cubic yard size planned for an optimum output of 320 c.y of concrete per hour, has been installed on the right side at EL. 1360, just downstream of the dam for the 1st stage concrete. This very plant will be shifted to EL. 1580 for concreting in the 2nd stage.

A special structure for batching and mixing plant will be erected at the site of the 2nd stage plant in advance so that the mixers and control equipment can be transferred there without loss of time.

Transportation of Concrete

From the batching and mixing plant, the concrete is transported to site in four c.yds bottom dump air operated buckets of scientific design. These buckets have been manufactured in the Nangal workshops. Diesel electric concrete cars with a capacity to carry four loaded buckets with room for another empty bucket move on rails and haul the concrete from below the discharge hoppers of the batching and mixing plant to a point below the cranes which pick them up and dump them in position.

Facilities for Service and Maintenance

The Bhakra Dam and Power Plant have got about 8 crores worth of equipment at the job. This has to be kept in trim condition and its repairs and maintenance have to be arranged round the clock. Most of this equipment has been imported from USA because such dams have only been constructed in that country. As the manufacturers are far away, it is necessary that the equipment is kept in proper position and adequate reserve of spares so that repairs can be quickly carried out without undue dislocation of work.

For this purpose the following facilities have been created at the project :

(*i*) Automobile repair and service shop
(*ii*) Locomotive service, fuel and lubrication
(*iii*) Euclid repair shop
(*iv*) Heavy duty repair shop
(*v*) Carpenter shop and saw mills
(*vi*) other field shops at Nangal and Bhakra

There is a well equipped field workshop at Bhakra for servicing and running repairs. Heavy repairs and overhauls are carried out in the project workshops at Nangal. The following fabricated steel structures have been produced at the project shops :—

(*i*) Structural steel work for about 4 miles of belt conveyor line
(*ii*) Cement silos
(*iii*) Towers for cooling plant
(*iv*) Columns and other members for processing plant.
(*v*) Sturcture for batching and miixng plant.

It is intended that the huge penstocks for the Bhakra Power Plant should also be fabricated at the project workshop. For this purpose a bending roll capable of handling two inch thick plate has been obtained.

The total outturn from Nangal workshops for fabrication of all the steel work is considerably above 5000 tons.

General

Engineers from all over the world have visited the Bhakra Nangal Project. They have been impressed with the best and latest contribution to engineering techniques. The staff writers of our organization have also been impressed with the tremendous and hazardous nature of the job. The Project engineers have with them the experience and know-how, which is more than a century old. They have previously constructed diversion weirs, barrages, lined and unlined irrigation system. The construction of the Bhakra Dam which they started eight years ago is no longer a new job. Adequate experience has already been gained and the operation of equipment is being admirably handled by Indian personnel. The best cooperation of foreign experts is also obtained because there is a complete spirit of informality on the job and every hand is deeply enthusiastic in doing a difficult job to the best of his ability. The work of design has been handled with success by the almost entirely Indian personnel who work at Delhi. Occasionally, a high powered Board of Consultants is engaged for advising on the more important technical issues which are reviewed.

The Problem of Mechanization of Construction

In all Indian Projects, the question of economical and efficient maintenance and operation of construction plant and machinery has now come to the fore. As most of the equipment has to be imported and cost of spares is also considerable, the financial implications of the use of equipment are becoming increasingly important. The criteria which governs the selection of plant and procedures that are working out satisfactorily on the basis of practical experience will surely be of interest of all the professional engineers, particularly those who are engaged on river valley projects.

With this object in view a few outstanding principles are worthy of notice which will help planners, project authorities and construction equipment trade in general towards securing the common objective of maximum utility and service at minimum cost.

The selection of equipment, its standardization, the policy of purchasing equipment on the basis of lowest tenders and selection of most suitable plant sizes are the main points which have a direct bearing on the cost. As in India for a long time to come, there will be a concurrent use of manual labour along with machinery in the interest of fuller employment, the principles evolved in India are to some extent, characteristic of conditions prevalent here and the blind imitation of the practices in vogue in western countries will not be judicious. In the light of the experience gained on the Bhakra Nangal project, certain observations become cogent. These are dealt with below.

Selecting right equipment

This important question hinges on the examination of the needs of the job from the civil engineering point of view. A detailed plan together with the estimate of quantities of work to be executed and the time schedule needs to be prepared. The layout of the construction plant has then to be decided after examining a number of combinations. This process ensures the co-ordination of the out-put of the various machines into an integrated scheme which would be clearly impossible if haphazard selection and purchases of machines are resorted to. Even on single projects there are various makes of equipment and machines. Far too many sizes in each category are procured and the situation created at the end of the brief initial period is a mess with its headache of a large variety of spare parts and accessories. Although it may be safely stated that most of the makes of equipment which are successfully selling in the market have something in their favour, yet for jobs of various sizes mutual satisfaction between the suppliers and users can only be on the basis of proved trouble-free service and fairplay. In this connection, the following findings are worthy of note :

1. Isolated small jobs are best done by manual labour because in the absence of proper workshop facilities. small mechanical equipment is liable to give trouble.

2. For big jobs it is a better investment to go in for larger sizes of equipment. These are sturdy and economical in the long run.

3. Minimum draw bar of 80 H.P. is recommended for Crawler tractors.

4. Shovels are best standardized in sizes of 1½, 2½, 3½ or larger capacities.

5. Minimum size of 10 cyds. for rear dump trucks. For bottom dump trucks, sizes of 12 cyds or over are profitable.

6. Compressors in the portable variety should not be under 315 cfm.

7. Power units should be purchased in multiple so that speedy replacements are possible.

Lowest tenders and their implication

If any manufacturer of an odd make was to sell his equipment merely on the grounds of price, project authorities should be most cautious in making such a purchase.

It is a greater headache to have to operate and maintain an odd piece of equipment and in the long run the purchaser loses rather than saves because of the cost of overhaul and repairs.

The following requisites are of over all importance :

1. At high level, governmental authority should approve a few well-tried makes.

2. The companies selected should guarantee that they will train project personnel.

3. For this purpose, skilled foremen and mechanics must be employed by the company for giving demonstration.

4. There must be agencies and distributors within India who can guarantee that atleast 75% of spare-parts will be kept in stock.

5. Rates for spare parts should be fixed on rate contracts.

6. Manufacturing of spare-parts in India should be started as a joint venture between Government and the foreign supply concern.

Phasing of Projects

From the point of view of equipment utilisation it is of the highest importance that river valley projects are phased not for a period of 5 years but for a period of 15 to 20 years. If this is done, the machines will be earmarked for work from project to project and there will be a double advantage. Firstly, the projects will get expedited due to availability of machinery in time, and secondly, the machines will be put to better utilisation and they will not be thrown on the scrap heap too soon.

It is obvious that workshop facilities and proper personnnel must be maintained at a high degree of efficiency. The question of spare-parts should be studied in a planned way so that the expensive machines should not have to sit idle without spares.

The companies in India are usually excelling each other in salesmanship without qualifying on the technical side for carrying out ready repairs. It should be made a condition that any firm who are expected to supply machinery will maintain a nucleus technical organization with enough practical skill to keep equipment moving for the maximum period without breakdown.

The whole question of equipment needs to be looked at from the modern stand point. The previous attitude that mechanical equipment will be looked after and set right by foreigners must be given up, if India is to march ahead on the road of maximum achievement.

Indian Contracting Companies

It is high time that the Indian contracting companies who are looking forward to contract for big jobs should specialise in the ownership and utilisation of modern construction machinery. Examples in other countries are not rare where single companies are organized for executing big jobs on codal contracts. Whereas in India, the Government subsidies with the initial finance for purchase of the machinery to a specified extent, further responsibility for keeping that machinery in good order and for preventing from deterioration must vest in the firms themselves and there should be definite conditions which determine that this desideratum will be available.

The accounting of expenditure on jobs where machinery is used is of the highest importance. A lot of expenditure can remain invisible in jobs where machines do the work, because with the capital cost already invested, there can be neglect in assessing the expenditures due to mechanised work. It has to be noted that awareness of the interest and depreciation charges must become more prominent in the minds of all ranks of workers before jobs can be tied down to suitable economic limits. It follows that from very beginning the question of equipment should be entrusted to men of knowledge and experience as it is in this field most particularly that advice of specialists is solely needed. In the case of the Bhakra Nangal project, the position regarding equipment has been examined in the greatest detail by the project authorities. They had hired very experienced engineers and construction superintendents in the layout of the construction plant and its proper utilisation. The Bhakra Dam is particularly an example where most modern equipment has been purchased and set up in order to obtain a very high figure for the daily outturn.

A list of the principal equipments is given below :

Principal Equipment Units at Bhakra Dam

Excavation Machinery

5½ cu.yd Ruston Bucyrus 120-RB electric shovel
2½ cu.yd Bucyrus-Erie 54-B electric shovel
2½ cu.yd Marion 93-M diesel shovel

1½ cu.yd Bucyrus-Erie 38-B diesel shovel
Allis-Chalmers HD 20 tractors
AF8 Ansaldo Fossati tractors
International TD24 tractors
Caterpillar D8, D7, D6 and D4 tractors
D4 tractors with traxcavator
Caterpillar 12 motor grade
31 Euclid TD rear-dump trucks, 22-ton
80 Euclid FD rear-dump trucks, 15 ton
1 Euclid UD rear-dump, 10 ton.
Le Tourneau-Westinghouse Tournarocker end-dumps.
Thames trucks, 4 cu.yd

NB.6.1

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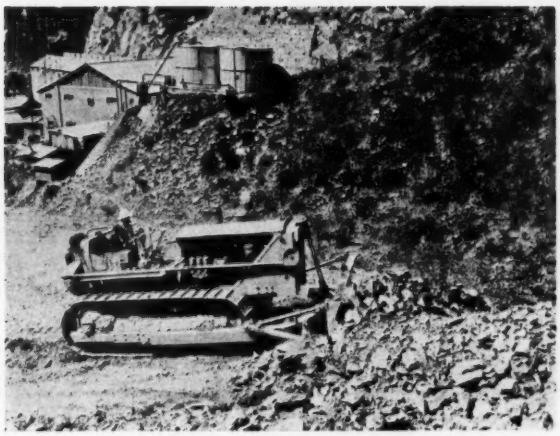

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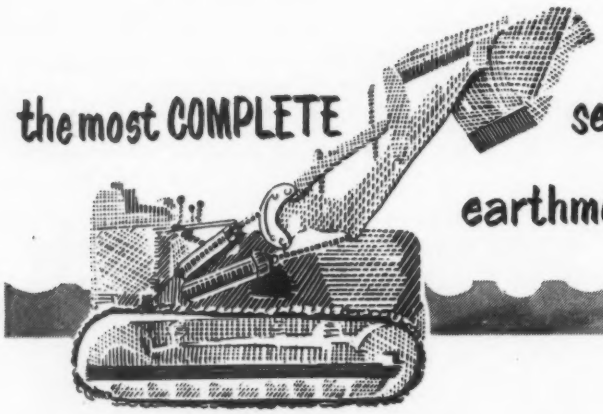

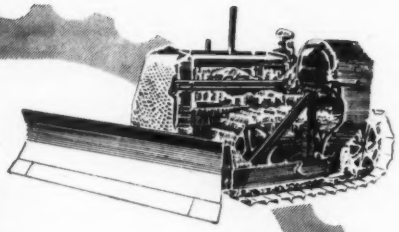

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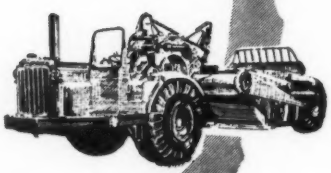
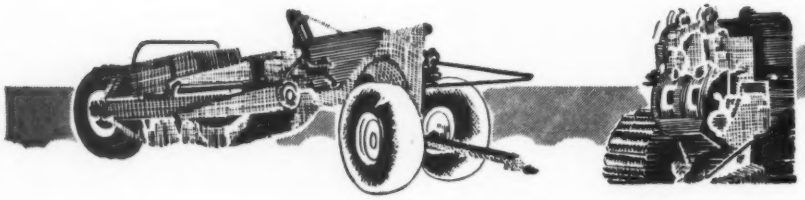
Worm Drive Winches	Root Rake	Forged-Trak Quarry Dump Trailers
Towing Winches	Brush Rake	Forged-Trak Tractor Trailers
Logging Yarders	Treedozer	Forged-Trak Stake Platform Trailers
Logging Arches	Stumpers	Forged-Trak Combination Trailers
Hystaway Crane and Excavator	Tree Cutter	Forged-Trak Wheels
Grid Roller	Root Cutter	





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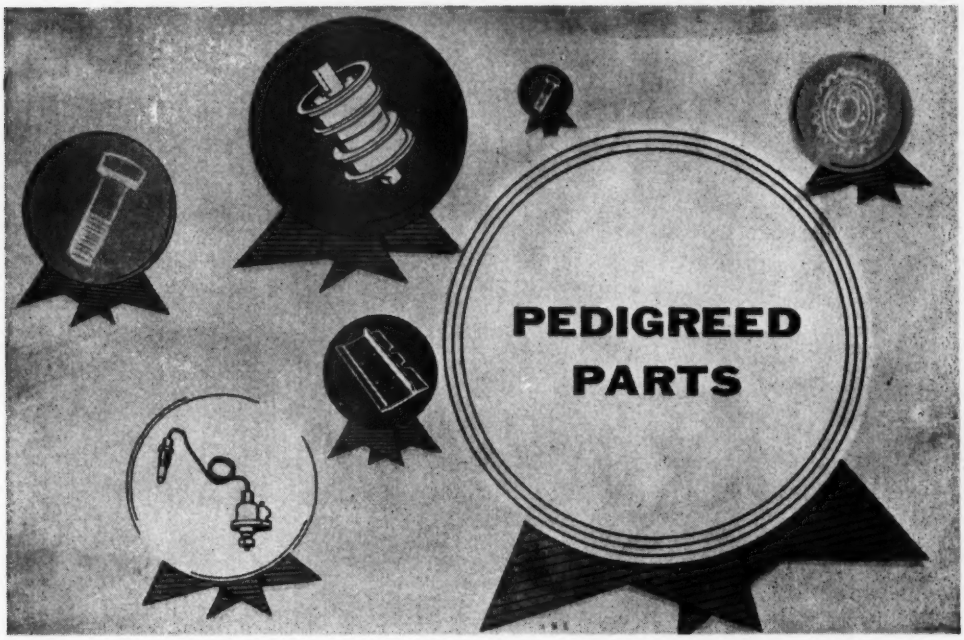

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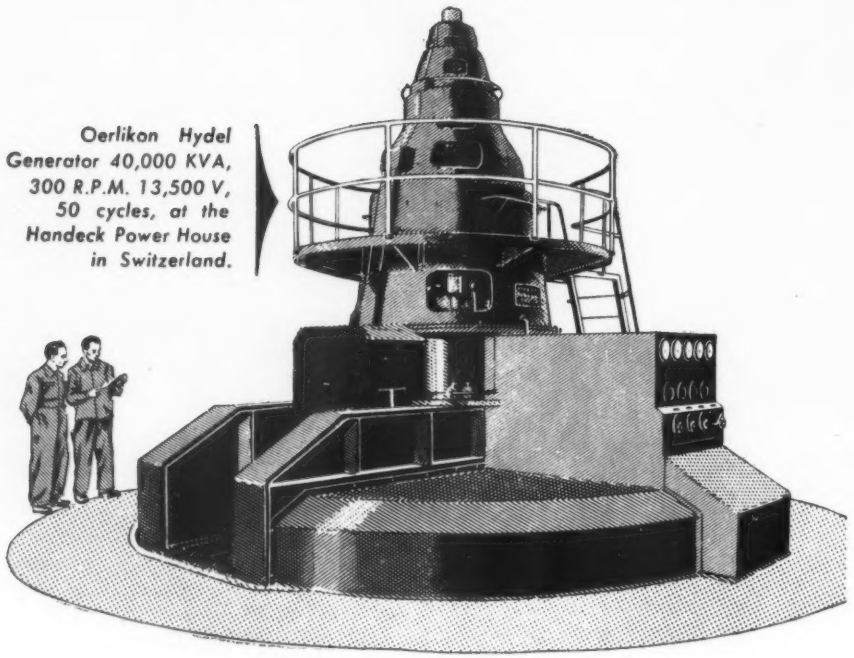

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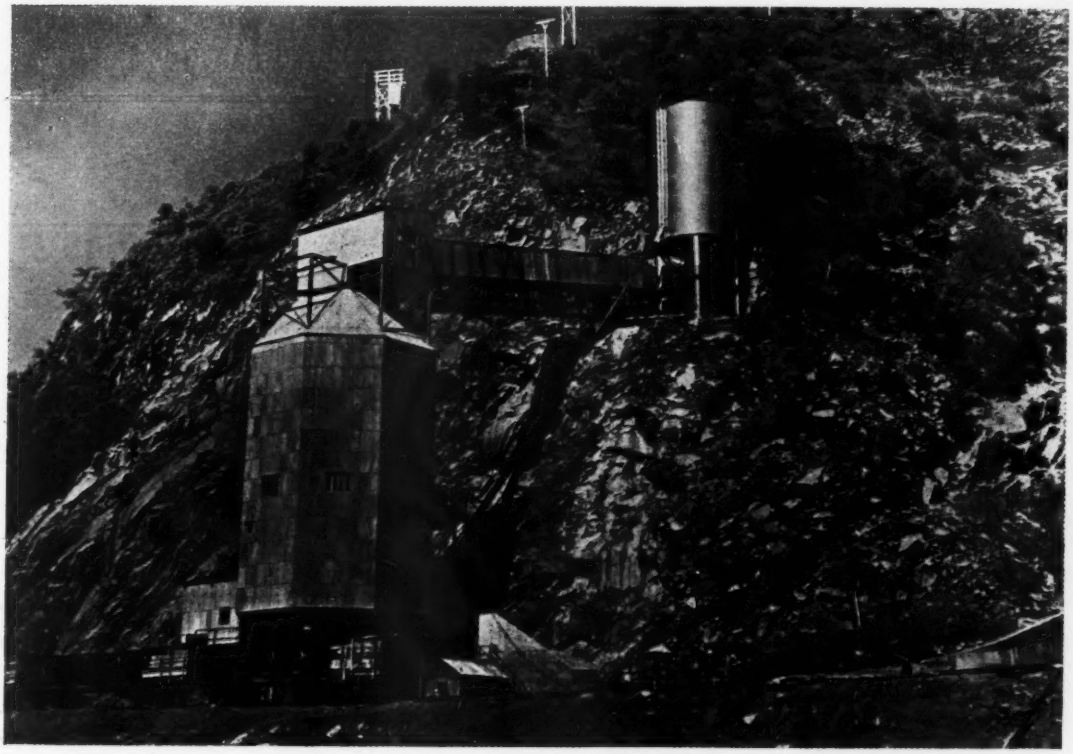

Batching and Mixing Plant at Bhakra

Northwest shovel, 1 cu.yd
P&H shovel, 1 cu.yd
Lorain shovel, 3/4 cu.yd
P&H shovel, cu.yd
Koehring Dumptors
Manitowe shovel-dragline combination
Link Belt-Speeder shovel-dragline, 2½ cu.yd
Lorain L-80j shovel-crane-drargline
Le-Tourneau-Westinghouse Carryall scraper,
Le-Tourneau cable dozer
Orton shovels, 3/4 cu.yd
Eimco 104 diesel rocker shovel, 1¼ cu.yd
Lima 1201 shovel, 3 cu.yd.

Processing, Batching and Mixing and Cement Handling Plant
8 Byron Jackson pumps
1 Portable field grizzly
Johnson Winget 320 cu.yd automatic batching mixing plant
Fuller-Kinyon type cement handling equipment.
Washington whirley crane
Colby whirley crane
Handerson stiff leg derrick
Ingersoll-Rand air hoist
Lorain 824, truck-crane, 45-ton
Lorain MC524 truck crane, 30 ton
International LFD 192 truck tractor
Fruehauf C-60 L 20-ton semi-trailer
International LFD302 truck tractor, incl. 5th wheel and Tulsa Winch
3 American revolver crane, 150-ft boom
2 American cantilever crane, 320-ft. boom
Rex 200 single Pumpcrete machine with 2 cu'yd Rex Pumpcrete machine with 2 cu.yd Rex Pugmill remixer
Blaw-Knox motor mixer
Koehring twin-batch pavers
Tourna mixers

Drilling Equipment
Joy rotary drills
Calyx drill
Joy class 12.B Diamond core drills

Railway Equipment
44-ton General Electric locomotives.

120 RB 5 Cu. Yd. Shovel

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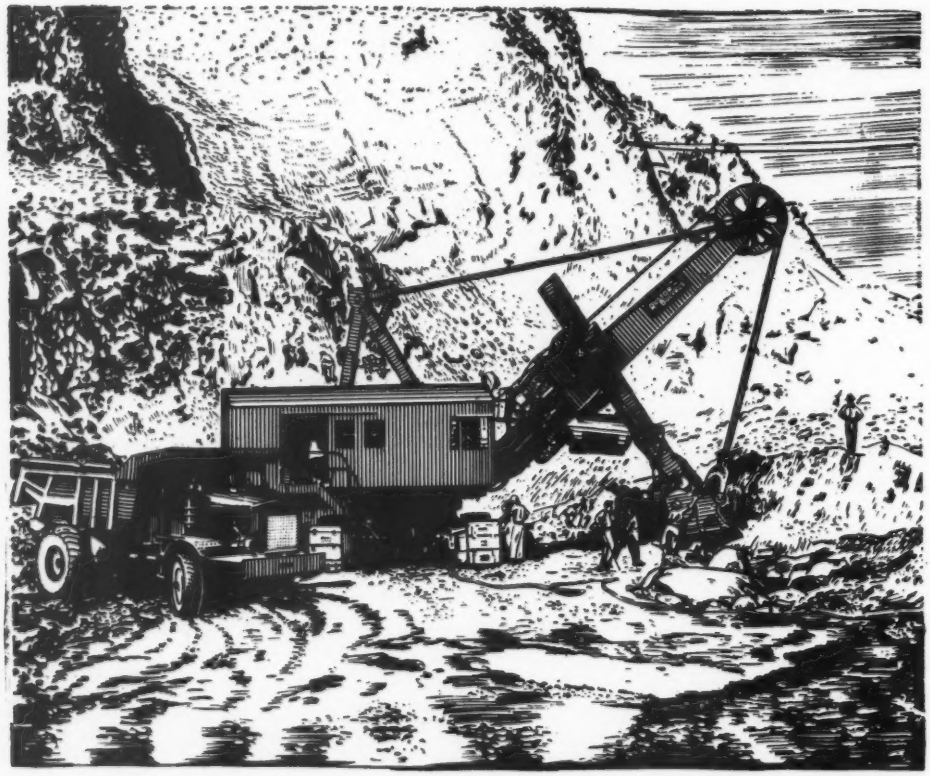
Dam site excavating in river bed for Dam Foundation.



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Dam and Appurtenant Works

The geology of the dam site has been described indicating its peculiarities. The description of the studies made for obtaining the best layout of the dam is given, culminating in the final scheme. The article then describes the gallery arrangements and tunnels for grouting and drainage, as also of the river outlets and the overflow spillway. The foundation problem of the Bhakra Dam has been discussed. The steps taken to assure temperature control of the mass concrete is then briefly described. The article concludes with the cost estimates of mass concrete used in the Bhakra Dam.

The Bhakra Nangal Project under completion in the North of India is unique in many respects. It constitutes a 680 ft. high dam for storing 7 million acre feet of water and generating over 4 lac kilowatts of firm power. On completion it will irrigate 6 million acres of land and benefit 30 million people of the Indian sub-continent. There are 3000 miles of channels fed from diversion dams which will acts in conjunction with the big Bhakra Dam now under construction.

The benefits from the project are about 1.13 million tons of foodgrains, 800,000 bales of cotton and 400,000 killowatts of firm power with a large amount of secondary power.

Geology

Predominantly sandstone but with important claystone and overall siltstone layers intervening the sandstone risens, is the description of the strata. The stratification is nearly right angles to the gorge with bed tilted at 70° downstream. At higher elevations, the abutments have a flatter inclination and at lower elevation the formation tends to become vertical. There is great variation in dip and trend and it is not possible to locate the dam within any particular uniform zone. Additional difficulties in foundation treatment result from this great non-uniformity of the foundation structure.

There are shear and thrust zones in otherwise sound rock. Jointing is seen both along and across the bedding planes. There has been a lot of weathering of the weaker claystone, siltstone bands. The claystone bands varies in thickness from a few feet to over 100 feet, just upstream and 70′ away from the axis of the dam.

Study for best layout

The dam has been located to rest upon the largest member of sandstone. Upstream and downstream, there are wide claystone bands which narrow the limits of location. Side walls of the gorge are steep. Although such a situation indicates an economical dam site, it magnifies the problem of finding room for accommodating the appurtenant works such as spillways, power plant, irrigation outlets.

A very large number of layout studies were made in India and America. Power Plant locations above ground and underground were also studied. At one time, a tunnel spillway on the model of Boulder Dam was included in the layout. Later on, this had to be omitted as the rock conditions on the left abutment were not sufficiently satisfactory. The conclusive scheme has emerged as follows :

(*a*) Straight gravity concrete structure for dam 680 ft. above lowest foundations, crest length 1617 ft.

(*b*) Slope of .8 to 1 from the lowest point at the d/s edge of the base to elevation 1662.5 with point of intersection at elevation 1700.

Above this elevation 30′ thick dam with downstream face vertical. Upstream face of dam has a slope of .35 to 1 from the base to elevation 1350 above which the face is vertical.

(*c*) Two towers placed symmetrically on the crest of the dam. The left tower provides access to the main elavator and the right tower to the hoist and service elevator. The elevators and hoists coupled with the galleries connect the interior of the dam.

Gallery Arrangement

A total length of 14,500 ft. of galleries have been provided. Rectangular in section, these galleries are 5 ft wide by 7 ft high.

Longitudinal foundation gallery are 6 ft. by 7 ft. for facility of drilling and grouting operations. In addition there are eight galleries, visitors galleries, cable galleries and pump galleries.

Tunnels for Grouting and Drainage

12 grouting and drainage tunnels of 6′×7′ size are provided into the hill side at different elevations. These are concrete lined and will serve to consolidate the abutment rock as drainage and grouting operations will be implemented, through these tunnels. At lower elevations, release of water will reduce uplift pressures and safeguard power plants from any harmful reservoir pressures.

River Outlets

Ten 15 ft. diameter penstocks and sixteen 8½ ft dia. river outlets will be available for providing the irrigation releases from the dam. The outlets are in two tiers of eight each at elevations 1320 and 1420. Whenever the discharge from the power plant is less than the irrigation requirements, these outlets would

A views of drilling operation in grouting and drainage tunnel at Bhakra

Finishing the concrete laid on the Dam

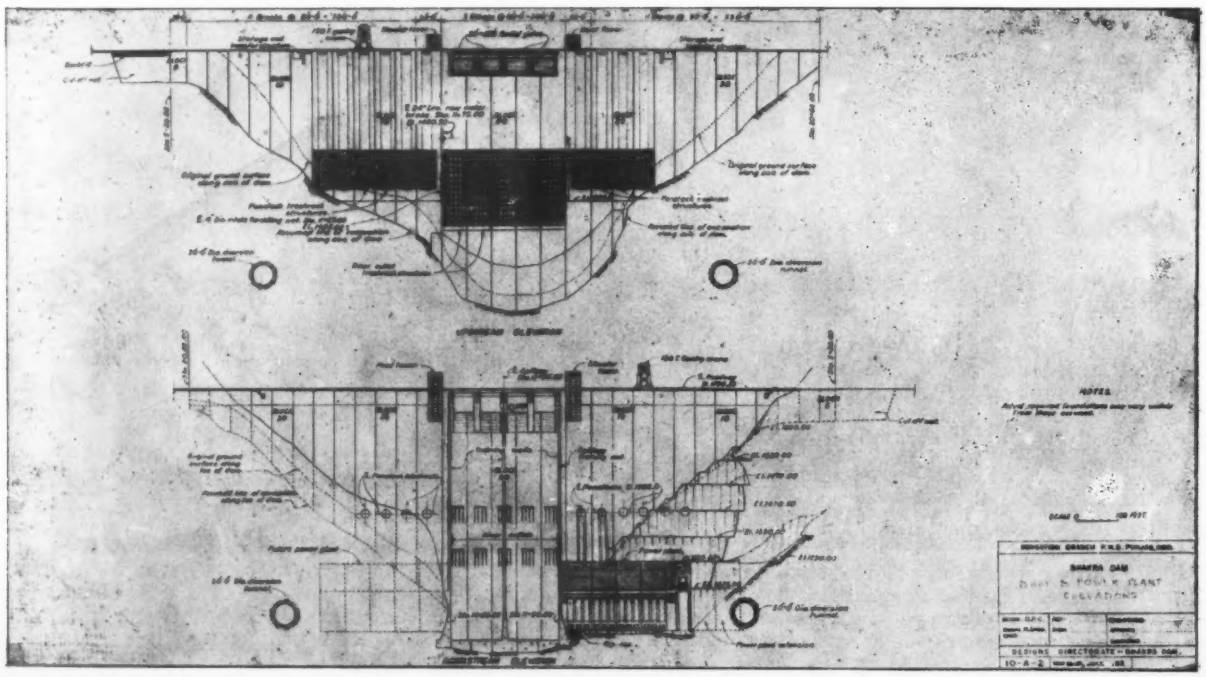
come into play. At maximum reservoir level, of 1680, the outlets can discharge about 105,000 cusecs. Thus these outlets can take care of 40% of the total required spillway capacity. In the outlets, jet flow gates will be fixed. These gates will have a maximum head of 368′ which is the highest for any such gate in the world. The gates have hydraulic hoists for their operation. The design of these gates has been done in conformity with the best hydraulic practice for sluice gates as in vogue in U.S.A. and Europe.

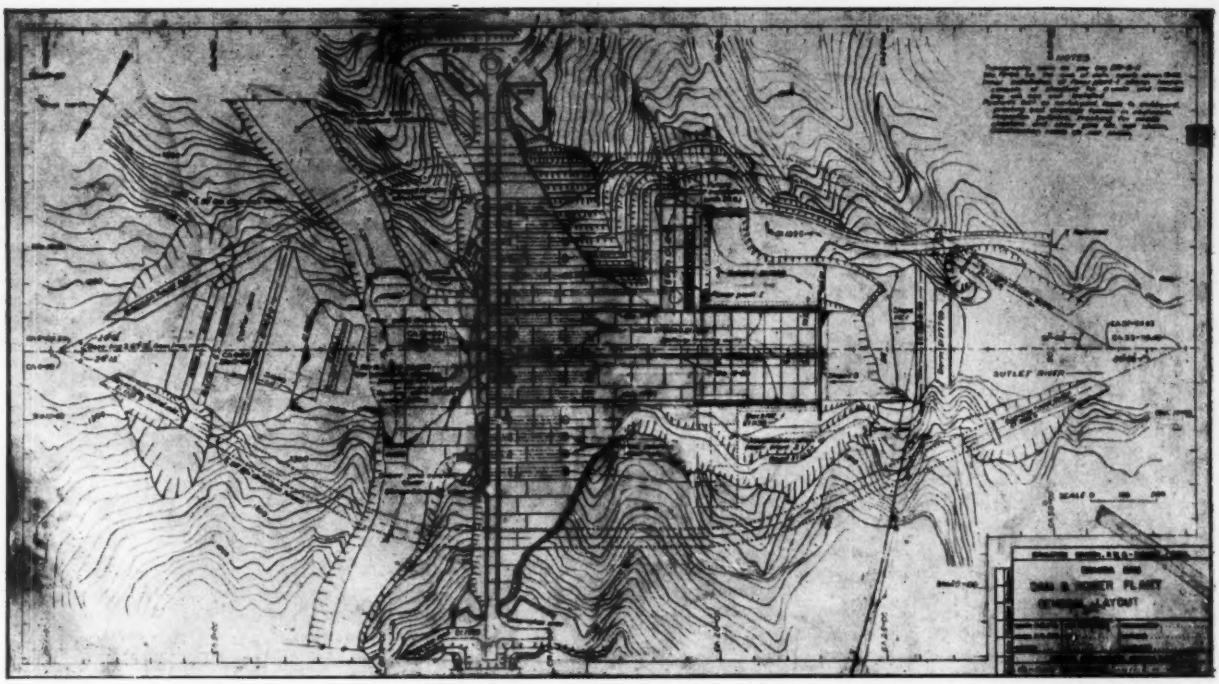
Overflow Spillway

Once in every thousand years, a flood of 3½ lac cusecs has been experienced in the Sutlej River taking the law of probability over the data available since 1909. One to ten thousand years, a flood of 400,000 cusecs may be expected. If this flood comes on a full reservoir at elevation 1680 and if the outflow is restricted to 2,90,000 cusecs, then 1685 is nearly the elevation to be attained. This gives a free board of 15 feet.

A 260 ft. wide overflow spillway is being provided with crest at elevation 1645. The discharge will be regulated by four radial gates of size 50′×37 . The spillway leads the flood waters into a cistern formed by horizontal concrete apron—the energy of falling water being dissipated on the hydraulic jump principle. The discharge intensity per foot run of the spillway is 1160 cusecs. The corresponding figures for Grand Coulee and Shasta are 894 and 900 respectively. So Bhakra Dam is again the biggest from this point of view. If one half of the spillway is required to be closed for inspection or repairs, the other half

Dam and Power Plant Elevations





Dam and Power Plant—General Layout

will be used for passing the discharge. This will be done with a central divide wall.

The Foundation Problem of Bhakra Dam

The word "classical" has been used by eminent engineers and geologists while studying the Bhakra's foundation problem. Yet there has been a consensus of opinion that the foundations are adequate and safe provided the proper foundation treatment is carried out. This treatment envisages the excavation and backfilling with concrete of claystone bands to adequate depths. Besides, a very thorough job of grouting is being undertaken for filling up the joints and seams that are met with in the sandstone strata. The use of chemical and fine cement grouting is also contemplated so that in the final stages the foundation of the dam is uniform dense and impervious. The network of galleries will provide access to various locations on the foundations.

Control of temperature rise and cracking of mass concrete

This largest dam has to be concreted in a period of three years taking the average placement of concrete at 5000 cubic yards per day. Hence undesirable shrinkage cracks have to be pevented and it has to be insured that the gradient of temperature is not so steep that it can give rise to cracking. The main features of the temperature control scheme are as follows :—

1. Transverse and longitudinal joints have been provided for dividing the concrete of the dam into blocks. Spacing of joints is 50 to 60 ft. in the transverse direction and 100 ft. in the longitudinal direction.

2. Concrete is to be poured in 6' lifts. Minimum interval of 72 hours to be allowed before the top of a lift is covered with fresh concrete.

3. Type I ASTM cement (Standard Indian cement) is to be used.

4. Precooling of concrete ingredients so that when depoisted in form, the concrete has a temperature of 65° F—which is also the temp. of a large portion of the dam.

5. Embedded system of thin wall tubing to be used for cooling the concrete to final stable temperature just before grouting of the contraction joints.

Study of Structural behaviour

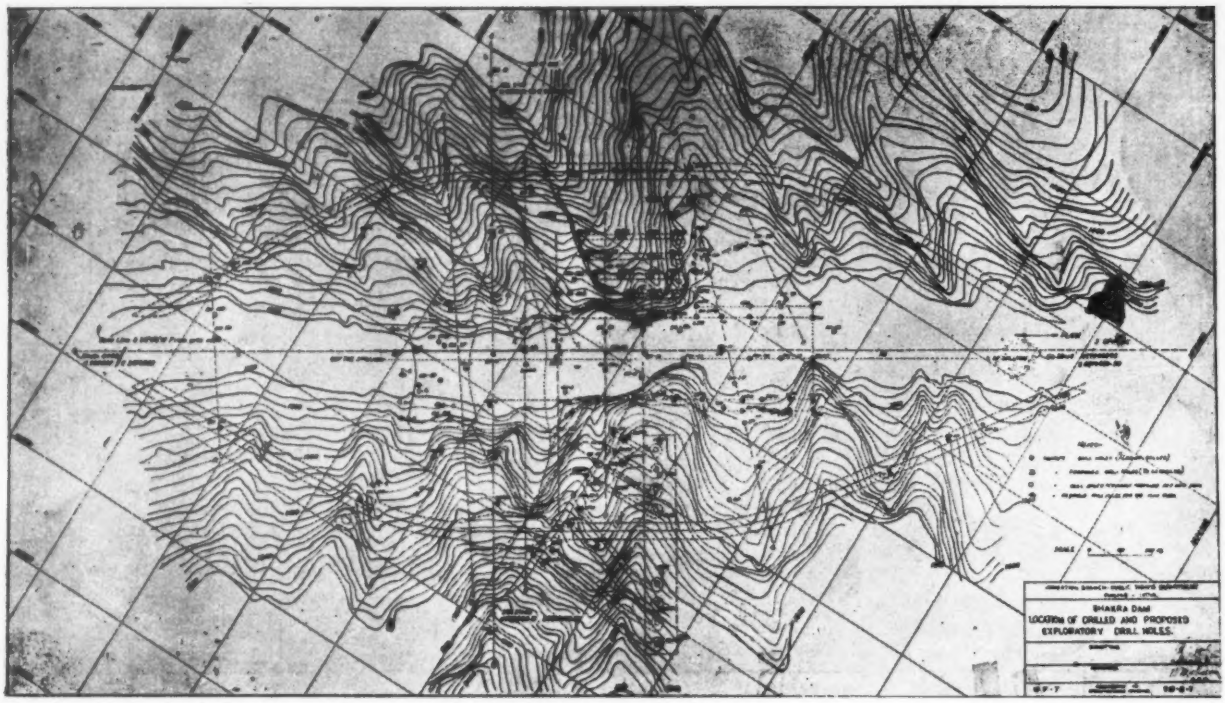
Thermometers for measuring temperatures, joint meters for measuring the openings of longitudinal and transverse contraction joints, stress meters and strain meters for measuring the condtions within the dam, are being installed.

These have been caliberated to enable studies being made of the structural behaviour of the dam on the basis of comparative data obtained from other dams where the same theories of stress distribution and behaviour of concrete have been assumed and tested.

Power Plant

This is described in detail elsewhere. The salient features are :—

(*a*) total firm power 400,000 K.W.
(*b*) Ultimate installation 10 units of 90,000 KW each. at Bhakra Power Plants and 6 units of 24,000 KW in two Nangal Canal Power Houses.
(*c*) Centre line of units of left power plant is 560' ft. downstream and parallel to powerplant with one edge of the building in line with the inner of the left training wall.
(*d*) Power Plant II with centre line of units at



Location of Drilled and Exploratory Drill Holes at Dam Site

about 580 ft. from the dam axis with four units each of 90,000 KW.

(*e*) Head variation from maximum of 512 to a minimum of 268.

(*f*) Rated output of 1,35,000 H.P. at design head of 400 ft. and speed of 166.7 RPM.

(*g*) Gnerators 50 cycle AC type each 100,000 KVA. These will have conventional two guide bearings, a thrust bearing on top and directly connected pilot and main excitors. Weight of each unit 1.6 million lbs. Diameter 44.5 ft. Height above generator floor level 32.5 ft.

Cost Estimate for Mass Concrete for Bhakra Dam

Materials

1. *Cement*	*per ton in$*
Cost ex-factory in bulk ..	10.063
Extra excise duty ..	1.048
Railway freight to Nangal Dam ..	3.354
Transportation from Nangal Dam to unloading site ..	0.463
Transportation to silos and batching plant ..	0.967
Total (per ton)	15.895
2. *Aggregate*	
Cost of raw aggregate at Bhakra ..	0.774
Aggregate classification—sand and screening plant ..	0.290
Aggregate reclaiming and transportation to mixing plant via cooling plant ..	0.107
Total (per ton)	1.171
Aggregate cooling	
Plant depreciation ..	3.019
Erection charges ..	1.059
Labour ..	1.614
Power electric ..	5.660
Supplies and spares ..	5.535
Total (per 100 tons)	16.887
Batching and mixing	
Plant depreciation ..	16.415
Labour ..	1.625
Power electric ..	1.656
Supplies and spares ..	5.241
Water charges ..	.021
Total (100 cyds)	24.958
Transportation to dam site including handling by crane	
Plant depreciation ..	44.947
Erection charges ..	24.488
Labour ..	6.457
Power electric ..	8.600
Supplies and spares ..	10.168
Total (per 100 cyds)	94.660
Concrete vibrators clean-up and finishing	
Plant depreciation ..	3.627
Erection charges ..	.423
Labour ..	2.474
Power electric ..	.482
Supplies and spares ..	10.482
Water charges ..	.021
Air charges ..	2.516
Total (per 100 cyds)	20.014
Placing concrete in dam including vibrating (per 100 cyds) ..	11.887
Shuttering (per 100 cyds) ..	78.618
Air entrainment (per 100 cyds) ..	2.621
Electric lighting (per 100 cyds) ..	6.29

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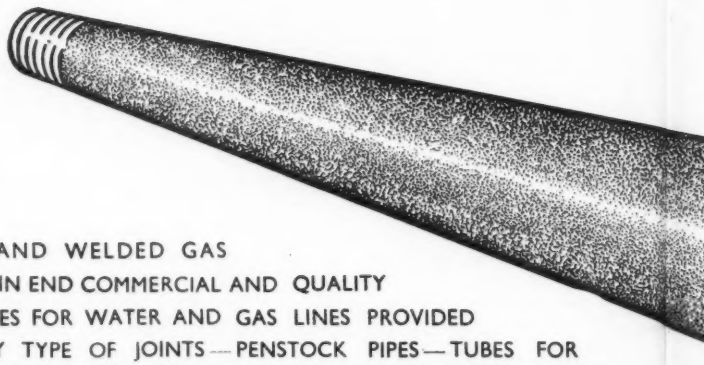

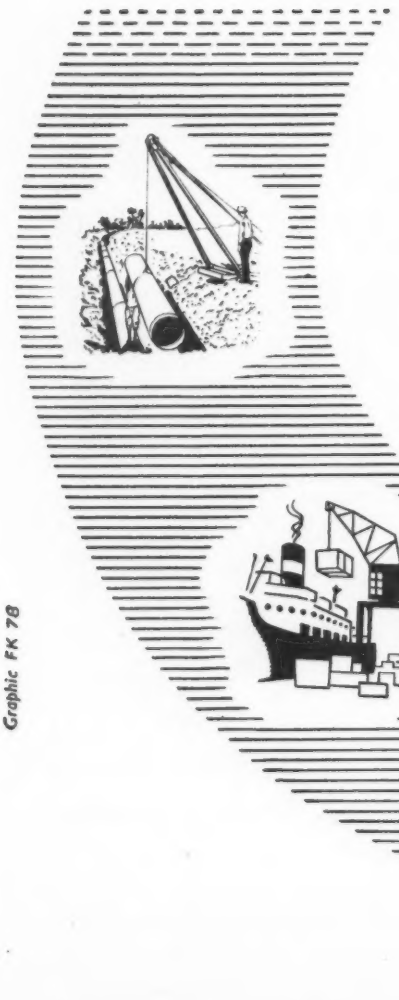

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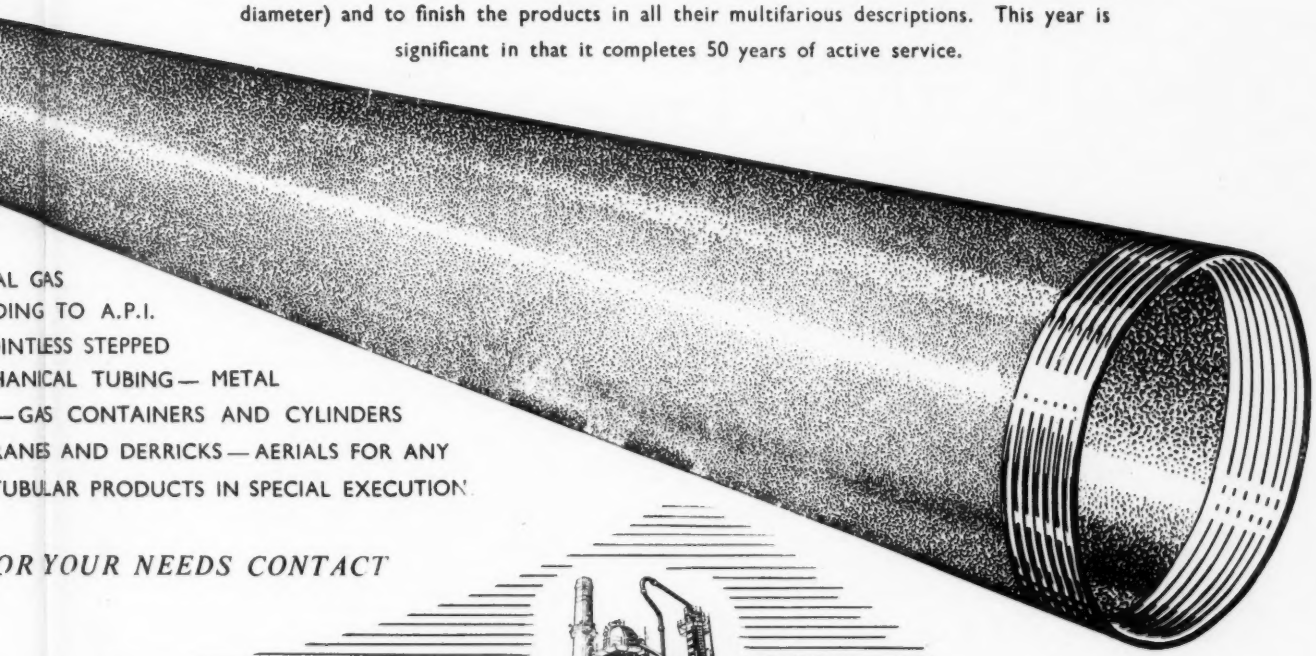

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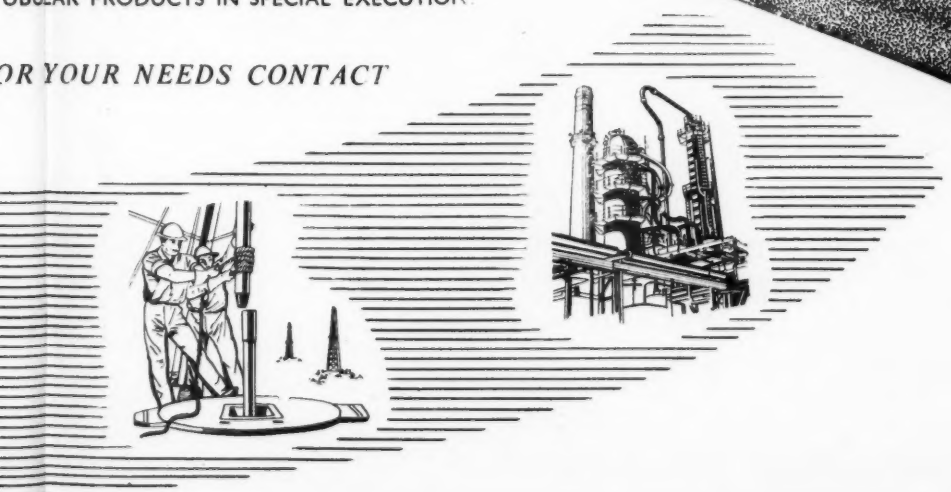

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Gates and Valves

The criteria needed to be followed in the model experiments carried out for the Bhakra Nangal Project, with special reference to the design of high head gates, are mentioned. The various shapes of the air chamber tried on the models are described. The designing of the gates and valves which has proved to be an extremely difficult problem in this case has been thoroughly described in this article. Various types of gates have been considered. The difficulty of becoming self-sufficient in this particular aspect has been discussed and important suggestions have been made. The role of the Amritsar and Nangal Workshops for such work in future have been considered. Emergency gate frames and guide engagement indicators have been dealt with. Hydraulic hoists and controls for jetflow gates have also been discussed. Gates for penstocks have been considered. Overhead travelling cranes and elevators for dam and power plants, steel penstocks and hoists, shafts, drawbridges have also been fully discussed.

In order to confirm the design for the high head gates, whether of the jet-flow, emergency or overflow type, model experiments are essential. The criteria which need to be follow on the models are best divided in the following main aspects :

1. The situation of the negative pressure zone in the whole length of a hydralic conduit, for example, river outlet in a dam.

2. The amount of negative pressure measured in feet of head of water in the various zones, taking into consideration the aeration provided in the design.

3. Whether the aeration provided is adequate or is more air or ventilation is needed in order to counteract the negative pressure.

4. The maximum air demand and the percentage of gate opening.

5. The maximum velocity of air in the headers.

6. The best shape of the air distribution chamber from the hydraulic and structural standpoint.

The models that have been constructed and operated at Malikpur and Amritsar have indicated that the negative pressure zones are concentrated just below the housing of the gates. The negative zone extends in the entire vicinity of the flow. At elbows and at bends more air needs to be inserted. All these factors have been taken care of in the final design. Some firms of manufacturers in Europe and America were also consulted and the general opinion is that it is liable to under estimate the amount of air required. It is better to err on the safe side by providing more air rather than less air.

Various shapes of the air chamber were tried on the models and it was found that 90° chamber is better than 100° chamber. This superiority was better from structural as well as hydraulic point of view.

It is said that on the Grand Coulee Dam, the velocity in the air-duct was so great at one time that an operator was sucked in with fatal effect. This factor has to be kept in view while designing the air-headers.

In the case of the emergency gates, the down-pull including friction has to be determined with the utmost care. In the case of Bhakra Dam gates, the value of downpull was found to be in the neighbourhood of 75 tons. The maximum downpull was seen to occur at 75% gate opening. The design of the hoists has to be based on the value of down-pull determined by experiments.

In the conducting of experiments of high-head gates, it is very vital to ensure that the friction coefficient of the material of the model does not render the results unreliable. It is therefore preferable to use plexi or perspex for model construction rather than concrete. In all modern Institutions of hydraulic research this principle is recognised.

Gates and Valves

One of the most difficult items in the Bhakra Nangal Project has been the designing of Gates and Valves for the control and regulation of water. In this country experience in these two items was of limited type because in the pre-independence period, the order for such equipment was confined alsmost exclusively to foreign firms both in the designing and fabricating fields.

However, for the Bhakra Nangal Project, the entire programme could only be completed if part of the work was done within this country. Particularly the designing of gates and valves was a matter which could not be entrusted to the foreign firms, firstly for lack of time and secondly, for want of data on which these designs and to be based, which could not be made available at the ouset. This data grew along with project because of the fact that capacities and head conditions were finalised with the progress of the design.

Hydraulic valves

Various types of valves have been evolved in

the U.S.A. in order to control the supply from outlets, penstocks and other works. Valves however, have not found a wide application because undesirable vibration has generally been witnessed. In the various types of valves, only the hollow jet has met with relatively greater success. This is essentially a needle valve in which the closing member points upstream. Water is discharged from bell-shaped valve body in a hollow jet form. The jet leaves the valves with very little dispersion of water at opening. The energy dissipation is thus distributed over a larger area in the spilling basin. The destructive forces are thus lessened and cavitation of the valve is also eliminated. It can be operated manually or with an electric motor.

Butter-fly Valve

This type is frequently used is penstocks for service or emergency closure. This is placed immediately upstream of the turbines scroll case. In river outlets. this is also used as a shut-off valve. The butter-fly valves are rather expensive and their operation is not as free from trouble as that of hydraulic gate.

Hydraulic Gates

These are of the following types :—

1. Bulk-head gates ; 2. Spillway gates ; 3. Fixed wheel gates ; 4. Coaster Gates ; 5. Embedded Gates ; 6. High pressure Gates ; 7. Ring-filler gates ; 8. Ring seal gates ; 9. Jetflow gates ; 10. Hinged type gates ; 11. Radial gates ; 12. Drum gates ; 13. Flap gates ; 14. Circular type gates ; 15. Cylinder gates.

Out of the above the jet flow gates, is the only leaf type which is capable of satisfactory design and operation for high head flow in close conduit. This type of gate can be installed at the discharge end of the conduit or in intermediate location. The leaf is mounted or wheels and is moved vertically by a motor driven screw-hoist or hydraulic hoist. Generally, in modern practice, jet-flow gates are equipped with hydraulic hoists. A new development of hydraulic sluices have made it possible to support the gates on oil at any position. Thus it is possible to hold the gate open in any position with the agency of a hydraulic hoist. The leaf and housing spring, the water passage are shifted to form a reverse which causes the water to issue in a jet at any gate opening. The outstanding feature of the jet-flow gate is that jet springs free and jumps past the wheel-slot on the sides of the conduit, thus preventing impingment of high velocity water in the slots. Air is admitted through pores located in the upper portion of the fluid immediately downstream of the gate. The air is distributed freely around voids formed between the jet and to avoid destructive magnitude.

In what follows, there are the typical specifications of the various types of gates that have been proposed for the Bhakra Dam. In this, only the main features are given and further details can be had from the project authorities.

Gates and Gearing manufacture: Types & Functions of Gates

The successful operation of a high dam is dependent on the proper design, manufacture and installation of the Gates and Cranes needed for the regulation of supplies which have to be surplussed due to floods or distributed for irrigation and power needs. In the case of the Bhakra Nangal Project, the equipment of gates needed for the Bhakra Dam has a speciai importance. This high dam includes an overflow spillway where the flood waters will be regulated by radial gates. Originally these gates were required to be of the Drum type, but later on, comparative economic studies revealed that radial gates would be more efficient and more economical in this case. Also the manufacture of radial gates was considered to be within the competence of the various workshops within the country, whether operated by Government or owned by the private sector.

Besides the radial gates, there are jet-flow gates for the river outlets and bulk-head gates equipped with rollers for the penstocks. Also, there are emergency gates which will permit the openings to be closed, and gates made available for inspection and repairs.

Need for Self-sufficiency

It has been felt by the authorities that in the interest of self-sufficiency, we must now develop the knowhow for the design and manufacture of high head gates. Such equipment is vital for the success of the project and it is high time that we recognised the necessity of more initiative and courage in this field. As it is, the firms in India or the Government workshops are not fully equipped for a proper solution of the design or the manufacture problems.

Specification designs

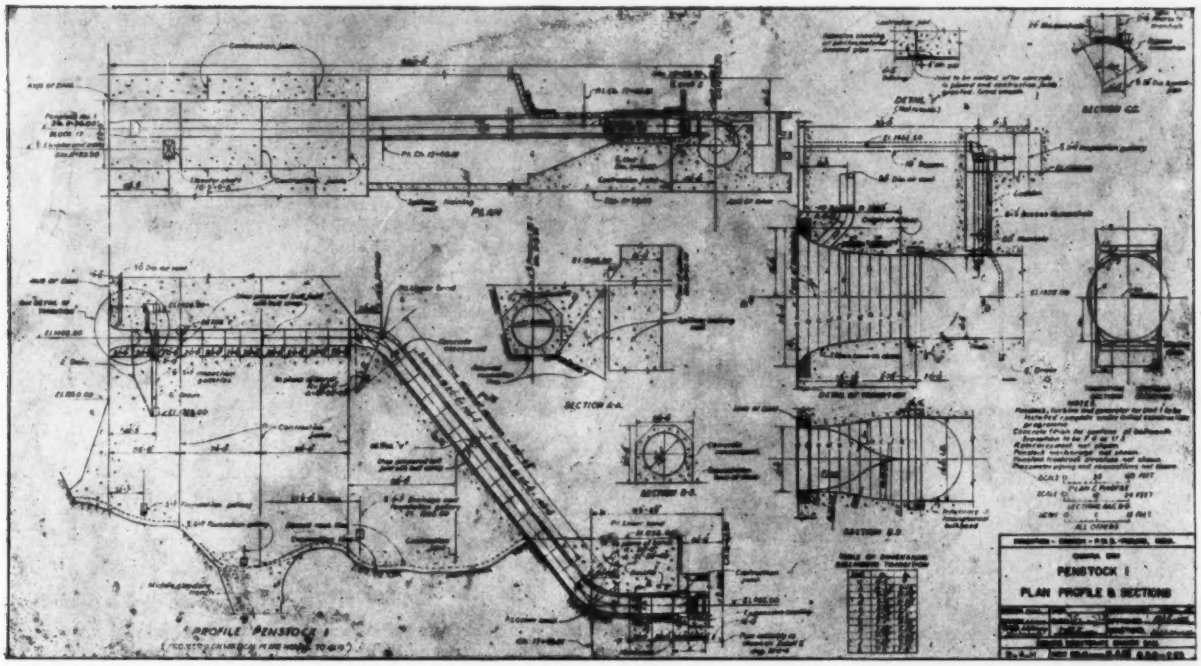
The concrete outline within which such gates have to function are easy enough to design on the pattern of similar dams. Hydraulic reasearch has advanced far enough to determine the regions of negative pressure or of turbulent flow. Provision can be made in the design for safeguarding against such deleterious features. The specification designs having been drawn up it is simple enough after that to call for quotations on a global basis, so that the latest techniques are adopted for the design and manufacture of gates.

Comparative bids

The bidding firms are usually required to give their cost quotation on the basis of specification design. Thereafter the responsibility for the detailed design is entrusted to firms subject to check and approval of their calculations and drawings. Only with such a proviso can the best use be made of the know-how, which is, as yet, more or less a trade secret with the firms. The check by the Government department enables safe value of factors of safety to be adopted in respect of the permissible stresses and other tolerances for efficient performance and durability.

Coordination of Standards

The important work of co-ordination of the design of foreign manufacturers with the standards prevalent in India can be ensured by suitable collaboration with the Indian Standards Institute, and the Director General of Supplies and Disposals. This former body has already done pioneer work in the matter of fixing standards for the specifications of various materials and the latter organization makes it possible for the construction agencies to depute inspecting staff taken out of the standard cadre of the Director General of Supplies and Disposals. In the case of



Plan Profile and sections of Penstock 1

major orders, the firms can be required to enable inspection of the manufactured items at the premises of their works. The results of their model studies can also be obtained in order to ensure that the performance of the gates on the prototype will be in accordance with the specifications.

Importance of Welding Standards

The key item in the successful manufacture of gates is that of welding. In this respect we are as yet deficient both in know-how and personnel. It is however high time that this specialization be started within the country and encouraged. It is only the first few sets of gates that will present any problem; subsequently the work is such that it can be duplicated with success.

Embedded parts

In order to govern the timely completion of the job of gates and gearing, special attention needs to be paid to embedded parts like guides and grooves. These are required much earlier in the process and if concreting operations are not to be delayed, these embedded parts should be available much earlier than the finished product. This can be arranged in liaison with the suppliers after the detailed designs have been approved. The tolerances which are permissible for embedded parts are, generally speaking, within the competence of the manufacturing workshops which are under the government departments incharge of the river valley projects.

Know-how for Gate manufacture

There is great dearth of experience and facilities in the field of gate-manufacture. The Punjab is one of the States where such facilities have been developed for the past three or four decades. Its Government Central Workshop have been charged with the responsibility of furnishing gates and gearing for river valley projects from 1930 onwards. They have successfully manufactured the gates and gearing for many projects in the joint Punjab and further development of their art needs to be perfected by giving them responsibility for the manufacture of gates for high dams and powerplants. There is a great potential of this work being done at the Nangal Base Workshop, which has been set up for Bhakra Dam. The experience available at Amritsar and at Nangal is likely to be pooled in order to produce a satisfactory and economical job.

10.97′×10.97′ Emergency Gates

These are used for the emergency clesure of any of the 102″ dia river outlet conduits. The gates will be operated by the 1500-ton gantry crane located on the roadway of the dam. For balanced head operations of an emergency gate, the jet flow gate will have to be closed first. The emergency gate, when guided in position, shall seal against the gate frame. The following are specified for emergency gates :

(1) Gate leaf and seals

Seal bases in the plates shall be finished after the plates and the skin plates have been stress relieved. Holes for the eccentric pins shall be bored thereafter. The seals shall be rubber-brass.

(2) Wheels

Wheel pins shall be solid stainless steel or carbon steel electroplated with nickel, the nickel coating being net less than 1/32″.

Bushings for the wheels shall be self-lubricating bronze inserts suitable for use in water.

Flat disc springs for the wheel assemblies shall be

either nickel-cooper-aluminium alloy or stainless steel.

(3) Assembly

The gates shall be assembled in a vertical position to assure proper alignment and all holes for field connections shall be drilled or reamed while each gate is assembled.

Each eccentric pin shall be retated 360° to insure satisfactory adjustment in all positions and each wheel shall be rotated not less than 10 revolutions to insure even distribution of bearing lubricant when each gate is fully assembled.

(4) Field Painting

The field painting shall consist of three coats of the coal tar paint C.A. 50 grade.

Emergency Gate Frames

The emergency gate frames will be embedded in concrete at upstream face of the dam behind the trashrack structure. The frames shall be such that the two emergency gates provided for 20 river outlets shall be able to fit interchangeably in any of the gate frames. When guided into position the gate shall seal against the gate frames.

The frames consist of seal seats and tracks. The faces of the corrosion resistant seal seats and tracks shall have the scale removed and shall be passivated.

Each emergency gate frame shall be completely assembled separately in the shop for inspection and to insure that all parts to be connected are fitted properly. Before shipment the horizontal members of each track and seal seat assembly are to be disconnected from the vertical members.

Emergency Gate lifting Frame and Guide Engagement Indicators for River Outlets

Lifting Frame

The lifting frame is used for lowering or raising the emergency gates and slot covers. It is provided at the top with a main lifting pin for attachment to the main hoist block of the 150 ton gantry crane while at the bottom it has a pair of hooks which engage with or disengage from the grapple mechaniser of the emergency gate or slot cover

The hooks actuated by a counterweight mechanism will either open out or close together automatically depending on the adjustment of the counterweights for the operation to be performed. Normally each hook is locked by a locking bar connected to its roller through a trip rod. When the disengaging rollers are pushed inward by the disengaging plates provided on the embedded disengaging beams the locking bar rotates unlocking the hooks thereby permitting free movement of the hooks. Before lowering the lifting frame to lift the emergency gate or slot cover the hooks are unlocked by the hand lever provided on the lifting frame.

When the emergency gate or slot cover is to be lifted out, the disengaging rollers are set in the correct positions. For this operation the counterwieghts are adjusted so that the hooks have a tendency to close in and the hooks are unlocked by the hand lever. The lifiting frame is then lowered until the hooks engage the grapple mechanism of the emergency gate or slot cover and come to rest. The lifting frame is now raised, the rollers sliding against the inclined surfaces of the embedded disengaging beams and operating the disengaging lever which locks the hooks from opening out accidently. Similar operations will follow when the emergency gate or slot cover is to be lowered into position except that the counterweights are suitably adjusted so that the hooks spring apart in the free position.

Guide shoes are fitted on the lifting frame to engage with the guide surfaces provided on the gate frames embedded in the dam. Indicators to indicate whether the guide shoes have properly engaged with the embedded lateral guides are also attached to the lifting frame.

Guide Engagement Indicators

A pair of indicators (one for the right side and one for the left) is required for each gate, lifting frame and each slot cover to indicate whether the guide shoes on the gates, lifting frame or slot covers are properly engaged with the embedded lateral guides.

Jet Flow Gates

The river outlets in Bhakra Dam are 20 No. 102″ dia. conduits with a 96″ jet flow gate for each conduit. These are lecated in two tiers at EL. 1320 and EL. 1420. Operations are conducted from gate galleries at EL. 1333 and EL. 1433.

The following specifications are issued for various parts :—

(*a*) *Bodies and Bonnets*

These shall be stress relieved before machining. Final finishing should be done after mating various parts.

(*b*) *Gate leaf*

Gate leaf shall be double stress relieved. First, after welding but before initial or rough machining and second, after initial machining but before final machining. Final machining of the u/s face should be done after giving a thin coat of slow drying paint. The hubs for each wheel axle shall be line-bored before final machining.

The entire jetflow gate shall be step assembled and all parts match marked and then dismantaled before shipment.

(*c*) *Seal rings*

Seal rings shall be endless rings made of natural or synthetric rubber containing net less than 1% of copper inhibiter.

The physical preperties of the compound shall be as follows :

Shear A duremeter hardness	55-60
Min. tensile strength	2,000 p.s.i.
Min. elongation (per cent)	450

Hydraulic Hoists for Jetflow Gates

Twenty hydraulic hoists, ten each in galleries EL. 1333 and EL. 1433 to operate the 96″ jetflow gates under unbalanced head of 300 feet of water. The

hoists are designed to work under a hydraulic pressure of 1000 p.s.i. Each hoist consists of bonnet cover, cylinder head, piston, stem, indicator and remote indicator system for indication of the gate position on a panel in the Power Plant control room.

Hoist Cylinder & Cylinder Head

The hoist cylinder and cylinder head, after stress releiving but before final finish, shall be subjected to hydrostatic pressure of 1200 p.s.i. for a minimum time of 30 minutes. Any leak in the welded joints shall be detected and repaired. The soundness and porosity of castings shall also be determined by these tests.

The shell of the hydraulic hoist cylinder shall be made of pierced and rolled steel forgoing or of steel plates rolled or forged to cylindrical shape. After the flanges have been welded but before final machining, the cylinder shall be stress relieved.

All parts of the hoist shall be completely assembled in the shop. It will then be tasted for its full working range and dismantled for shipment. All the parts are matchmarked to facilitate assembly in the field.

Controls for 96″ Jetflow Gates

The control equipment for the 96″ jetflow gates consists of five control cabinets and one power cabinet for each of the five gate galleries. Each control cabinet will be located on the wall between the twin gates and will house all the operating controls required for each pair of gates.

The power cabinet will house the motors, pumps and electric equipment and will furnish the power for all the gates in one gallery.

The gate operation will be manually actuated from the control cabinet only whereas the remote indication of the gate position is provided in the power plant. The control system is designed for 1000 p.s.i. oil pressure and the gate will close at a uniform speed in about 8½ minutes under full head. In each gallery, the gates shall be operated only one at a time.

The power supply to the control units will be 3-phase 400/440 volt, 50 cycles A.C.

The following accessories are provided :

(1) *Oil pumps*

The pumps shall be suitable for pumping oil at temperatures ranging from 40°F to 100°F and shall have a capacity of about 7.2 g.p.m. at a pressure of 1000 p.s.i. when operating at 1000 r.p.m. The pumps have 1″ suction and 3/4″ discharge pipes.

(2) *Oil filter*

The inlet and outlet of the metal edge type filter is 1¼″ pipe and its mesh shall have not more than .003″ spacing. Its rated capacity shall be at least 17 g.p.m.

(3) *Four-way valve*

Its rates capacity is 23½ g.p.m. and a working pressure of at least 1000 p.s.i. The valve shall be tapped for 1″ pipe.

(4) *Sequence valve*

The valve shall be tapped for 1″ and 1/4″ pipe connection. The valve shall have an adjustable range of 150 to 250 p.s.i. and shall be set so that a pressure of 200 p.s.i. is required on the remote pilot connection to actuate the valve.

(5) *Relief valve*

Its rated capacity is at least 15 g.p.m. and a pressure range of approximately 500—1000 p.s.i.

(6) Pressure switch, pressure gauge, oil gass gauge, oil and air filter units and check valves are also provided.

Electrical accessories required e.g. motors couplings, control switches, combination switches strip heaters, toggles switches and terminal blocks are also specified.

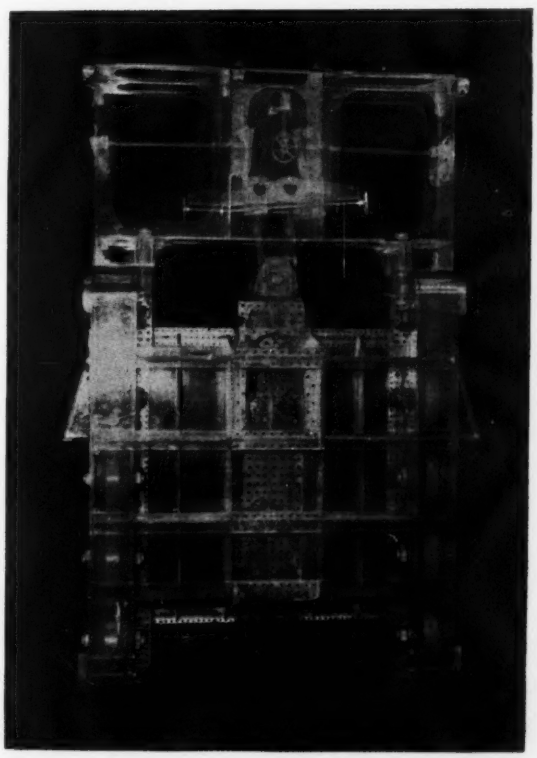
Gates and Gate Frames for Penstocks

The penstock gates will be used for

(*a*) Emergency clesure of the penstocks &
(*b*) Closure of penstocks for the inspection and maintenance of penstocks and turbines.

Normal operation of the gates shall be under balanced heads but they may be lowered to close the penstock entrance under an unbalanced head of 314 feet (including 34 feet vacuum head). The max. flow through the turbine would be 3600 cusecs. The gates shall be capable of withstanding the dynamic loads resulting from emergent closure and static load due to the draining of the penstock after normal closure.

Model of the Emergency Gate



Retracter type gate seals and roller bearings for wheels have been proposed to decrease the total frictional forces.

Gate

(1) *Leaf* : The gates shall be fixed wheel type having either antifriction or self lubricating bearings and metal covered rubber seals. The gate is divided into four (approximately equal) sections for easy transportation.

(2) *Wheels* : The wheels in the gate are so spaced that the transmission of leads to the concrete through the back is evenly distributed. The wheels shall be non-flanged with a min. tread Brinnel hardness of 260. The grease chamber shall be provided and connected to the d/s side of the skin plate.

The lubricating area shallnot be less than 25% of the total area of the bearings and the bearing stress shall not exceed 3700 p.s.i.

Disc springs for centring the wheels shall be provided at each side of each wheel and be designed to centre the wheels laterally whenever they are relieved of load.

The lowest part shall have one extra wheel on each side in order to avoid stilting of the gate.

(3) *Seals* : Metal covered rubber seals are provided with thin brass facings.

(4) *Shoes* : Spring loaded guide shoes shall be provided at each side of the gate, top and bottom, to automatically centr the gate between the guides when it is relieved of load.

Gate Frames

(1) *Purpose* :

(*a*) Providing a track upon which the gate wheels will roll and which will transfer stresses to concrete.

(*b*) Providing a flat surface against which the gate seals will seat.

(*c*) Providing a guide which will limit both transverse and lateral movements of the gate.

(2) *Seal seats.* Seal seats shall be of sufficient width to provide an adequate surface against which the gate seals will bear after taking into consideration the max. lateral movement permitted by guides.

(3) *Track and Trackbase.* The gate deflections will be compensated by the combered underside of the track.

(4) *Guides.* These will limit the transverse and lateral movement of the gates to not more than $\frac{1}{4}''$ in either direction from the normal position.

Hoists

The capacity of the penstock gate hoist will be 400,000 lbs at a working pressure of 600 p.s.i. The travel of the hoist piston is 26 ft. 8 ins. The intermediate stress shall of circular section and $6\frac{1}{2}''$ min. diameter.

River Outlets Cast Iron Conduits

The C.I. conduit is the upstream portion of the R/O conduit (upstream of Jetflow gate). The downstream flange of the C.I. conduit unit will be bolted to the upstream flange of Jetflow gate. Each conduit assembly measures $26'\text{-}10\frac{1}{8}''$ and consists of four units. The lengths of the parts are :—

1. Bellmouth	..	6′-6-5/8″
2. 3. Intermediate units	..	6′-8″ each 13′-5′
4. End unit	..	6′-10″
		26′—10-1/8″

Each C.I. conduit shall be completely assembled in the shop for inspection and to insure that all parts of each unit are properly fitted and that all dimensions and clearances are obtained as per specifications. The units will be dismantled before shipment after being match-marked.

15-Ton Overhead Travelling Crane

This crane is provided in each of the two $12' \times 19'$ gate galleries at EL. 1333 and EL. 1433. These are required for the maintenance of the jet flow gates and the hoists.

The crane shall be hand operated, indoor, single trolley, double girder overhead travelling type. The crane hoist shall be of the wire rope and driven type.

In the design a proper allowance shall be made for wear impact, and for collision with track stops when the bridge or trolley is travelling with rated load.

The crane consists of

(*a*) Bridge,

(*b*) Rails

and (*c*) Trolley.

(*a*) *Bridge*

The bridge shall consist of two girders designed to carry the full rated load of the crane without undue vertical or lateral deflection, vibration or stresses.

End trucks shall form rigid box sections carrying wheels in bearings. The bridge movement shall be effected by pulling on an endless chain hanging within 18″ of the floor level.

(*b*) *Rails*

Two run-way rails for the crane travel of about 300 feet are provided.

(*c*) *Trolley*

The trolley shall be supported on four double flanged wheels to fit the rails.

The hoisting mechanism within shall consist of a train of gears, automatic mechanical load brake, winding drum and operating wheels and chains. The lifting tackle shall consist of a block and hook, necessary sheaves and flexible flow steel wire rope.

All spur gears shall be designed to take the entire load on one tooth. Pinions shall be made of forged carbood steel or heat treated alloy steel. Provision shall be made for grease lubrication through high pressure fittings.

75-Ton Travelling Crane

The 75-ton Crane will be installed in the Hoist

Chamber of the Right Diversion Tunnel for installation, maintenance and final salvaging of the gates and hydraulic hoists. Four hydraulic hoists will be installed in the chamber operating the four gates installed in the 50 feet diameter tunnel below the hoist chamber. The crane shall be transported to the hoist chamber for intial installation through a 16′-6/8″ vertical shape and then through a 8′ wide ×12′ ×10′ 6″ high gallery. For salvaging, the crane shall be taken out through the same passage.

The crane shall be electrically operated, indoor, single trolley, double girder overhead travelling type, controlled from the operator's cage. The capacity of the crane shall be 75-imperial tons provided with an auxiliary hoist of 20 imperial tons capacity.

The required clearance and other data shall be as follow :

Span, centre to centre rails.	30 feet.
Travel of bridge.	42 feet.
Travel of trolley.	25 feet.
Lift.	68.00 feet.
End clearance between the hoist chamber walls and crane.	6 inches min.
Top clearance ; hoist chamber ceiling and crane.	6 inches min.

Bridge

The bridge shall consist of girders supported on end trucks. The girders shall be designed to safely carry the full rated load of the crane without undue vertical or lateral deflection or vibration. Each and truck shall form a rigid box section.

All the bearings shall be roller, ball or sleeve type with removable bronze linings. The drive shaft and all connections from the motor to the driving truck shall be designed to transit at least 60% of the driving power. The bridge travel of the crane shall be affected by means of an electric motor mounted near the centre of the bridge.

The bottom of the operator's cage shall be at least 20 feet above the floor of hoist-chamber.

Trolley

The trolley shall be equipped with a main hoist and an auxiliary hoist. The hoists shall be mounted on the trolley frame work and driven by suitable electric motors and gears to obtain the required hosting speeds. The trolley drive shall be effected by means of a motor mounted on the trolley frame and connected through gearing and shafting to the driving wheel. A separate self-contained automatic brake to hold and control load under all conditions shall be provided. The lifting tackle shall consist of a block and hook, necessary sheaves, and flexible steel wire rope. Provision shall be made for grease lubrication through his pressure fittings.

Gears

All spur gears shall be designed to take the entire load on one tooth.

Electrical equipment

The motorrs shall be of the wound rotor type rated at 415 volts, 3 phase and 50 cycles A.C. supply. Its rated capacity shall be such that the specified performance of the crane does not exceed the full load torque of the motor. Controls shall be provided so that it is possible to limit the movement of hooks within 1/32″ and 1/16″ for the main and the auxiliary hooks respectively and 1/4″ for the bridge and trolley while carrying the full rated load. All the conductors for power and control shall be insulated for 600/660 volt grade, moisture and heat resistant insulation with adequate capacity to carry the full load current without injuring the insulation. The hoisting limit switches shall be of the hook block actuated type.

Elevators for the Dam and Powerplant

The elevators are intended primarily for use in connection with the construction, operation, inspection and maintenance of the Bhakra Dam and Power Plant No. I.

Each elevator shall be of the electrically operated type designed for direct current operation by a generator field control system and shall be arranged only for manual control.

Control

The control and operating system of each elevator installation shall consist of an individual motor-generator set and a motor operated direct current elevator machine.

Car operating panel

Each car shall be equipped with a suitable operating panel flush with the interior of the car. Car position indicator, landing buttons, slow speed switches etc. shall be provided for operation.

Car frames

The car frames shall be constructed of heavy structural steel substantially reinforced and braced so as to relieve the car enclosures of all strains. Guides shall be provided at the top and bottom of each side.

Car enclosures and emergency exits

Car enclosures shall be made of sheet steel and shall be suitably reinforced and braced. Two emergency exists shall be provided in the car, one located at the top of the car and the other at the side.

Safety devices

Each elevator car shall be equipped with a suitable can safety device so as to stop the car with any load upto the maximum specified capacity, should the speed of the car when descending, exceed the tripping speed for which the car governor is set.

Governors

Each elevator shall be equipped with a governor which at a speed slightly in excess of the rated car speed will open the motor and brake control circuits so as to bring the car to a smooth stop and apply the brakes in a proper manner.

Slow down & stopping device

These shall be provided in each elevator. The car when approaching the terminal landing or any intermediate landing as selected by the operator will automatically slow down and stop.

Buffers and self levelling systems are also provided in each elevator.

(*Continued on page* 72)

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FROM

THE PUNJAB GOVERNMENT

FOR BHAKRA POWER HOUSE NO. I

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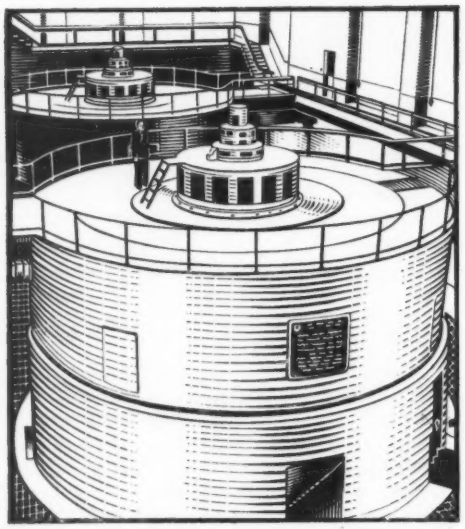

BRIEF SPECIFICATION

Vertical-shaft, single-runner, single-discharge, spiral-case Francis turbines.
Output : 150,000 H.P.
Effective head : 400 ft.
Speed R.P.M. : 166.7

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W. J. 56. 4.

Bhakra Dam Power Plant

The description of the power plant is first given. The deatils of the design of the hydraulic turbines are then discussed. The runners, the shafts, the guide bearings, the wicket gates, the servo motors, the speed rings, scroll cases, draft tubes are then described. Then follows a description of the governors and their accessories.

Bhakra Power Plant No. I is being sited on the left bank of the River downstream of the left abutment of the dam. The longitudinal axis of the building and generating units is nearly parallel to the axis of the dam. There will be space for five generating units and a service bay. Initially all the five units will be installed in quick sequence. When the project for the Bhakra Dam construction started, it was considered doubtful whether there will be load enough for more than one unit. But, the subsequent development of the load has outstripped all expectations. It is now quite in the picture that even all the five units may not suffice for the load development of the next five years. Hence the construction of the right power plant may also be on the programme for present construction activities.

The centre line of each turbine is at elevation 1165. Individual steel penstocks about 730 ft. long with separate trashracks at the inlet end will convey the water to the runners. Penstock diameter is 15 feet. There are transitions at the lower ends to reduce diameter for suiting the inlet of the turbine scroll cases. The Governors of actuator-type working with oil pressure at elevation 1178 will control the ouput and speed of the unit. A service highway and railroad along the left bank of the river will connect the power house with the main rail road. The transformers will be installed on a deck adjacent to the power house wall on the side of the tailrace. The station auxilliaries will operate with power supplied at 50 cycles, 400 volts, 3 phase AC or 230 volts single phase AC. 220 volt direct current supply will also be available. The other important particulars to help the design of the turbines are as follows :

1. Mean annual air temperature	73°F
2. Variation from mean monthly	54°F in January 88°F in June
3. Mean monthly river water temperature	4°F Dec-January. 69°F Aug-September.
4. Maximum air temperature	113°F
5. Maximum river water temperature	86°F
6. Relative humidity	99% at 94°F dry bulb temperature

Note :—The record of 29 years has been consulted to arrive at these figures.

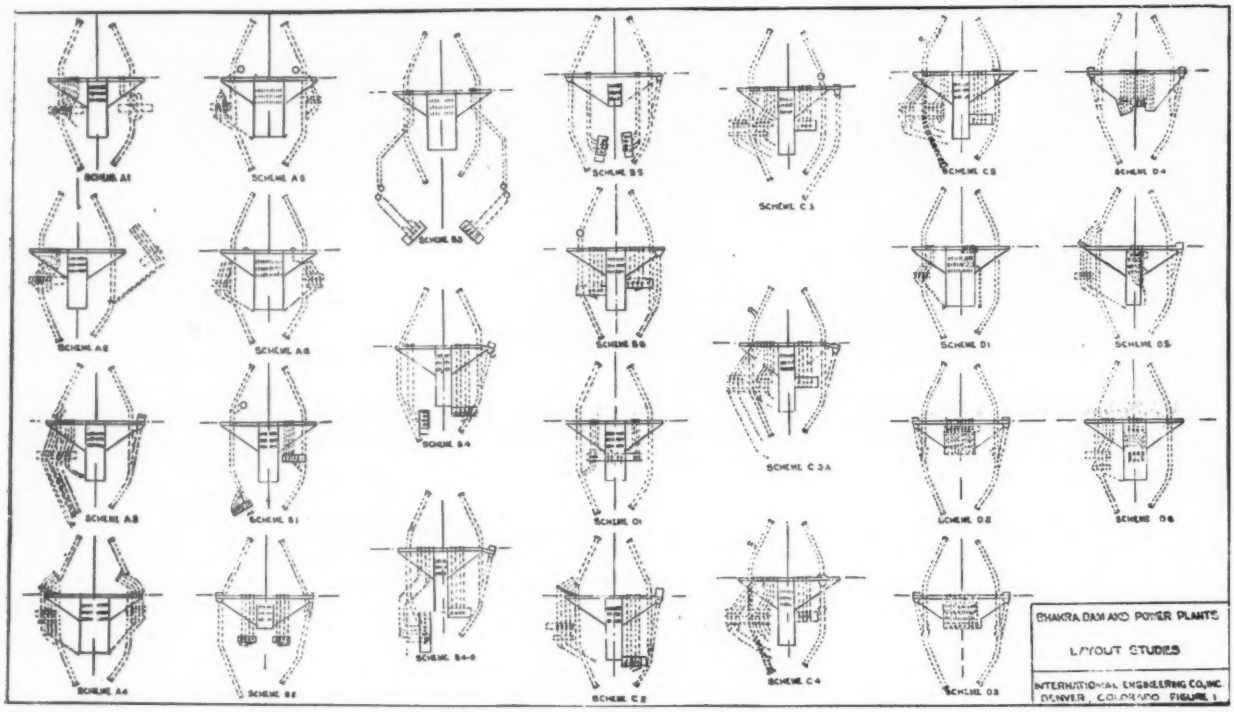
Important details for the design and construction of hydraulic turbines

The turbines are required to be of the vertical shaft, single runner Francis type. The spiral casings are to be made of steel. Rotation of turbines is to be clockwise looking down on the units. The spiral casings are to be embedded in the concrete substructure of the powerhouse. The fabrication of the turbines is to be so arranged that vertical movement of the shafts and runners can be secured by one inch to adjust and dismantle the generator thrust bearings. It is also necessary that the design of the turbines should secure that all removable parts can pass through the openings in the generator foundation and stator which is approximately of 19 ft. diameter.

Variation in head due to irrigation needs

On account of the fact that Bhakra Power Plant has to cater for irrigation and power needs simultaneously, the storage in the big lake gets depleted very fast and out of all proportion to power needs alone. There will be a maximum head of 512 feet and a minimum head of 268 ft. The average effective head has been taken as 370 feet. The design flood maximum levels have been taken at 1685 for head water and 1215 for tail water. The minimum levels have been taken at 1440 for head water and 1166 for tail water. It has to be insured that the turbines can operate at all gate openings throughout the above range without causing vibrations or surges.

The capacity of each turbine is to be 1,25,000 horse power at point of best efficiency. The gate opening corresponding to best efficiency is 80 to 82% of full gate. The speed is 166.7 R.P.M. for an effective head of 400 ft. The generator rating is the limiting factor and the gate opening of the turbine will be restricted accordingly. The generators are rated at 1,00,000 KVA at .9 P.F. lagging. There is, however, provision for 15 percent continuous overload on the generators. The operation at run-away speed is the governing factor for design, although the normal speed for turbine operation is to be 166.7 revolutions per minute. The runners of the turbines can either be fabricated or castings. The design may be solid stainless or ordinary cast or fabricated steel with stainless steel overlay or insert on water passages. Each runner will be strong enough to support its own weight or that of the turbine shaft. When the shaft is disconnected from the generator shaft the



Layout Studies of Bhakra Dam and Power Plants

runner is resting on the lower section of the speed ring. The runners are to be balanced statically in the manufacturers shop. For attaching runners to the turbine shaft there will be bolted flanged connections. The surfaces of the runners have to be free from hollows, tracks or projections so that there is no pitting or cavitation. The lower 1/3rd of the runner passage must have a very smooth and uniform surface.

The guarantee from manufacturers is to cover a period of one year from the date that the runners are brought into commission at head of 268 feet or higher. The standard of cavitations will be measured by the erosion of 500 cubic inches or more of metal, on the upper permissible limit. So far as the quantity of suspended matter in the water is concerned, it will naturally not be a responsibility of the manufacturer. However, with the very high heads under which the power plant is to operate, it can safely be predicted that the huge depth of the Bhakra lake will have excluded harmful silt in the decantation process.

The shafts of the turbine will consist of forged open hearth carbon or alloy steel properly heat-treated. The turbine shafts have to be of proper length to connect with generator shafts. They will have forged flanged half couplings on the upper ends for connection to similar half couplings on the lower ends of the generator shafts. The turbine shafts are to be machined accurately. The most important requirement is the accurate alignment of the turbine and generator shafts. For this purpose, it may be necessary that the generator contractor may have to deliver the generator shaft at the works of the turbine manufacturer. With this step, a careful check of the alignment of each assembly can be made. The coupling flanges of the generator shaft will be in subdrilled condition. Reaming to size will have to be done by the turbine manufacturer. For the facility of the generator manufacturers, a template will be supplied by the turbine manufacturer for subdrilling of the flange of the coupling. Usual standard precautions will be necessary for the coupling bolts.

Guide bearings of the turbines

These will be of the babitt-lined oil-lubricated type. Located above the runners, these will have bearing supports and removable bearing shells each split vertically into two or more sections to facilitate dismantling. The supports of the bearings will be steel castings or welded plate steel so that they can transmit the load safely to the speed rings.

If the guide bearing of the turbine is to be pressure lubricated this will be provided with two pumps in order to secure effactive and positive circulation of the oil to the bearing. One of these pumps will be a service pump driven by a 50 cycle 3 phase, 400 volt alternating current motor and the other an auxiliary pump which is operated from a direct current motor, 220 volts. If there is any failure of the normal oil supply there should be an automatic alarm to indicate. Similarly there should be an automatic arrangement for starting the auxiliary pumping units. The lubricating oil will be cooled if necessary by a suitable external heat exchanger. The temperature of the available cooling water has been taken as not over 30° centigrade.

The flow of oil to the bearing inlet shall directly

take place from the strainer outlet. The capacity of the lubricating system should be enough to supply the required amount of oil to the turbine guide bearings, which will have all accessories to indicate vapour pressure through thermometer and thermal relays. The contacts of the relays are to be suitable for use on 220 volt direct current circuit. The oil piping is to be of seamless copper tubing and will be complete with instruments and gauges for indicating the smooth operation of the turbine bearing lubricating system. It will be particularly essential that the guide bearings do not let any entry of water in the lubricating system as also to be leak proof.

The operating mechanism for wicket gates

Moveable wicket gates or guide vanes will control and guide the supply of water to the turbine runners. Each wicket gate will have not less than 1/8th″ deep stainless steel coating pre-welded to it on the inside face and the outflow edge. The width of the coating will be 2″ on the inside faces. This will extend inside from the line of contact formed by an adjacent gate when in the closed position and to the full height of the gate. In the outflow edges, the coating will extend to a width of 3/4 inch on both faces. The chemical content of the stailess steel coating ((placed in two equally thick layers) will be as follows :—

Chromium 25% for first layer, 18% for second layer
Nickel 12%for first layer, 8% for second layer
Silicon under .6 percent for first layer, same for second layer
Carbon under 1% for first layer, same for second layer
Columbium 6 to 10 times carbon content for both layers

Where feasible stainless steel inserts may be substituted for the coatings. The thing to guard against is objectionable variation. For this purpose the number of turbine guide rings and the number of water passages in the runners are to be coordinated. The gates themselves and gate stems are to be of steel castings or seal forgings, but in one piece structures. Sleeves will be provided for noncorossive surface over the lower stems of the gate. These will be of suitable durability and of accurate finish. The sleeves are to be shrunk on the stems and will also be welded to the stems at the lower ends. The vanes are to be able to withstand a strain equal to the breaking stress of the gate lever shearing links, with the obstruction of over four inches on the tips of the vanes. The gates are to be interchangeable and should have three guide bearings, which are fitted with bronzed bushed pressure greased and pressure lubricated. Each gate stem will have an adjustable thrust-bearing locked securely in position and capable of taking a thrust upward or downward so that the gate may be supported in mid position between the curb and crown plates. In the design of the upper stems of the gates, there should be provision for any future machining of the portion passing through the bearings without reducing the stem diameter below the fit required for the gate levers. The gate operating mechanism must have ample strength to withstand the maximum load under the most severe operating conditions. Lost motion and wear should be reduced to the minimum in the operating mechanism and if any individual gate requires adjustment it should be possible to do it independently of the other gates. Also if any individual gate becomes disconnected from the gate shifting mechanism no part of the gate should come in contact with the turbine runner, otherwise the failure of one shear can cause progressive failure of adjuncent shear bins. The operating mechanism and connection for control of the wicket gates shall be located outside the turbine casing so that ready inspection, adjustment and repair may be possible. Similarly the bearings must also be readily adjustable for maintenance.

The Servo Motors

Each turbine gates are to be operated by two oil pressure double acting hydraulic cylinders which will have a combined capacity adequate for exerting necessary force with a minimum oil pressure of 250 pound per sq. inch. This pressure may rise to 270 or 300 lbs. per sq. inch. The time in which a servo motor shall be capable of moving the turbine gates a full opening or a full closing stroke is four seconds. This will occur at the oil pressure for which the hydraulic cylinders are designed. During operation, any slipping or rocking of the servo motors is to be prevented by adequate dowel pins and anchor bolts. The force of moving the turbine wiket gates will be approximatly divided between the two cylinders and each of the cylinders are to apply this force in an equal magnitude on the opposite side of the gate shifting rings. The servo motors will be operated and controlled through oil pressure which will be regulated by the Governor actuator. In order to operate efficiently, the servo motor cylinders shall be accurately bord provided with flanges to connect the oil supply and with stuffing boxes to prevent oil leakage along the pistol rods. The pistons of the servo motor will be of cast steel or cast iron and each piston will have not less than three cast iron piston rings for the prevention of leakage past the piston. The Governor restoring mechanism and the gate operating mechanism will be efficiently interconnected. The rate of closure from slightly below the speed-no-load position for maximum head to the fully closed position will be capable of uniform retardation through the action of the servo motors. There will also be suitable mechanical locking devices which will hold the turbine gates securely in the open or closed position. The travel of the turbine gate mechanism in the opening direction from the closed to the open position without interferring with the travel in the closing direction with be limited by an adjustable positive mechanical stop which can be locked in position. This will limit the output of the turbine positively.

Speed Rings

These will be made of cast steel or welded plate steel. They should be designed to support the weight of the superimposed structures including the weight of the generators and should be within the safe capacity. When the scroll cases are empty bursting stresses in the scroll cases for an internal pressure of 290 lbs. per sq. inch should also be within its capacity. The speed rings will be made in sections to correspond with the section of the scroll cases. If the stroll cases are of the cast steel type then the speed rings will be cast integral with these. If however, the scroll cases are

of the plate steel type, then the speed rings are to be shop welded to scroll cases. The speed rings will have bolted flange connection for the pit liners and rivetted or bolted flange connection for the draft tube liners. During erection the application of jacks will be done over a sufficient number of machines which must be furnished. In the lower sections, provision for grout holes is necessary to facilitate the placing of concrete under speed rings.

Scroll Cases

These are to be made of cast steel or plate steel with flanged and bolted sectional joints. The design hydrostatic pressure is 290 lbs. per sq. inch. The scroll case inlet will be suitable for fitting the downstream ends of the penstock which ought to be made of steel plate 1-2/3 inch thick. The design of the casings should permit the removal of all internal parts of the turbines from above. The bottom cover plates and discharge rings are of cast steel or welded plate steel and have to be bolted in the lower flanges of the speed rings. The scroll cases will be filled with water and prestressed with an internal hydrostatic pressure of 220 lbs. per sq. inch while the concrete is being placed around and over the scroll cases. The size of the scroll cases will permit the operation of the turbines at rated capacity and under the normal rated head so that the velocity of the water at the centre line of the units normal to the inlet sections does not exceed 28 ft. per second.

The construction of the scroll cases will be in radial segments with flanges for bolting the sections together. The inner surfaces at joints between adjoining sections of the cases shall be flush by an amount not greater than one half of the nominal shell thickness. At junctions of flanges and bosses the shell thickness will be increased to reduce concentration of stresses. Chipping of the inner surfaces will be permissible by an amount not exceeding one half of the nominal plate thickness. For a plate steel scroll case the steel plate flanges and speed link sections shall be welded together to form complete radial segments and shall be stress relieved in the shaft. The Bhakra Dam authorities have the option to have the scroll cases manufactured in their own workshops. However, in such a contingency the complete design and drawings of the scroll cases will have to be furnished by the turbine supplier to enable local manufacture.

Draft Tubes

The design of the draft tubes upon which the guaranteed efficiency and performance of the turbine are based is to conform to the space limitation available at the Bhakra Dam Power Plant concrete structure. The draft tubes are to be of the elbow type with two intermediate piers in the horizontal portion below the elbow. The elevation of the draft tube floors will be adjusted so as to obtain the most economical costs for power house excavation and substructure concrete. Either cast steel or welded plate steel can be used for draft tube linings. In the place of plate steel liners the thickness shall not be less than 3/4 inch. Cast steel pier noses for the draft tubes are to be included with the draft tube linings. The pier nose shall be provided with fillets at the top and bottom to conform to the shape of the concrete passages. It shall be designed to support a load of 1.5 million pounds.

The plate steel draft tube linings shall be reinforced on the outside by means of suitable ribs and shall have adequate means for secure anchoring to the surrounding concrete. The linings shall be completly assembled and all stiffner ribs and braces on the outside of the linings shall be accuratly fitted. Before shipping the linings will be completely knocked down and match marked. It is optional for the Government that they may delete the draft tube linings from the contract of supply and have them manufactured in their own workshops. As in the case of scroll cases, the supplier will however have to furnish the design and drawings for the draft tubes.

The above general description of the turbine parts applies in essentials also to the turbine pit liners which are to be of welded steel not less than $\frac{1}{2}$″ thick. They are to reach the elevation of 1178.

With these turbines, a number of instruments will be furnished to indicate pressures. Similarly indicating dial thermometers of the vapour pressure type and the industrial thermometer of the mercury type would also require to be provided.

For removing any leakage that may occur within the turbine pits, adequate drain pipe connections are to be provided. Cast iron pipe drains 4″ diameter will be left in the concrete substructure in the vicinity of the section. There will be gravity drainage within the turbine pits. If this is not possible under any circumstances then motor operated pumps will also be used.

Shop and field erection and tests

The turbine shall be completly assembled in the shops and properly match marked to insure correct assembly and alignment in the field. In case the assembled casings are to be furnished by the supplier these will be tested under internal hydrostatic pressure of 440 lbs. per sq. inch. The hydrostatic tests will be repeated by the Government under the direct supervision of the contractor's representative, after assembly and erection in final position in the power house and before embedment in the concrete.

The acceptence tests after the turbines have been installed will be made by and at the expense of the Govt. The test code used will be the same as for hydraulic prime mover published by the American Society of Mechanical Engineers.

Governors

These shall be of the oil pressure relay valve actuator type with an electrically driven speed responsive element. These will be readily adoptable for automative synchronizing and for automative load and frequency control. Each Governor shall be complete with actuator, restoring mechanism, two motor driven units, pressure tanks, sump tank, oil piping, independent alternating current generator, for supplying power for the motor driving the speed responsive element. The normal operating pressure will be between 250 and 300 lbs. per sq. inch. and the entire governor oil pressure system shall be designed for an operating pressure of 300 lbs. per sq. inch.

Governor Rating

The Governor shall be rated at not less than the

capacity for the servo motors. They shall be capable of supplying an adequate quantity of oil to the servo motors so as to operate the turbine gates to a complete closing or opening stroke in four seconds with an initial oil pressure of not more than 250 lbs. per sq. inch. and with the maximum head of 680 ft. including water hammer on the turbine. The servo motors shall be provided with adjustable bypass connections whereby the rate of closure may he retarded during the portion of gate travel from slightly below the speed-no-load position to the fully closed position.

Actuators and Controls

These will be located in the Governor gallery at elevation 1117. The speed responsive element of each actuator shall be driven by an alternative current motor receiving power supply from the permament magnet self excited alternating current generator which will be a part of the Governor equipment. Due allowance will be made for a vertical movement of the main generating shafts without dis-assembly of any part of the independent generators. The following specific control devices will form part of the equipment.

1. Gate limit control 2. Speed level control 3. Speed drop control 4. Manual gate control 5. Automatic shut down 6. Generator Brake control 7. Gate-position indicators 8. Speed level indicator 9. Speed drop indicator 10. Speed indicator 11. Pressure gauge 12. Pressure gauge oil for governor oil pressure tank. 13. Over speed switch 14. Low speed switch. 15. Pressure switch. 16. Gate limit switches. 17. Dome light 18. Cabinet lights 19. Atutomative speed-no-load control.

Governor Oil Pumps

Each governor will have two motor driven pumps of screw type having a combined capacity per minute of three times the total oil volume of the servo motor of the turbine. There will be necessary pressure tanks sump tanks and piping.

MARSHALL, SONS & CO., (INDIA) LIMITED

Messrs. Marshall, Sons & Co., (India) Limited are one of the largest Engineering firms in India having been in business for over eighty years now. They have very *actively contributed to the building of the Nangal Hydel Channel* and the Bhakra Canals by supplying over 100 Fowler Marshalls Mark VF Diesel Crawler Tractors, each fitted with a 'Marshall' 40 HP. Diesel Engine. These Tractors were used *on compaction where they were employed in pulling double drum temping sheeps foot rollers.* The fact that such large quantities were used by a single Project in itself shows the high reputation these Tractors have earned for themselves.

Messrs. Marshall, Sons & Co., (India) Limited are now again contributing towards the building of the Bhakra Dam as they are to supply Emergency and Regulating Gates for the Right Diversion Tunnel with Gateframes and Hoists and also Gates and Gateframes for the Penstocks. This equipment will be built in Austria by Messrs. Waagner-Biro A.G., Vienna, who are specialists in Hydraulic Steel Structures. This firm of Vienna is of over 100 years standing, having first established their work in 1854 and today they are by far the largest Austrian firm specialising in the manufacture of a number of products like Hydraulic Steel Structures, Steel Bridges, High Pressure Pipe Lines, Cranes of all types and description, Boilers, etc. etc.,

Messrs. Waagner-Biro have one works in Graz and three in Vienna of which the works in Graz is the largest and all these four works are very well equipped for producing High Grade Precision work. At Graz Messrs. Waagner-Biro have installed the largest and the latest Annealing Furnace in Europe which is very necessary for the fabrication of Hydraulic Steel Structures where stress relieving plays a very important part.

Messrs. Waagner-Biro have only very recently come into the export market, as previously they were busy in the reconstruction of their own country and now they are only supplying Hydraulic Steel Structures to the Bhakra Dam but they are also supplying this type of equipment to the Aswan Dam in Egypt and the Snowy Mountains Hydro Electric Authority, New South Wales, Australia.

Power for the Millions by **AEI**

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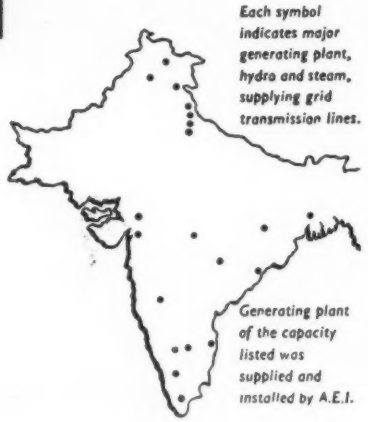
Ramgundam	37,500 KW
Ahmedabad	1,35,000 KW
Surat	15,000 KW
Visakhapatnam	6,750 KW
Tatanagar	55,000 KW
Kashmir	6,000 KW
Jogindarnagar	48,000 KW
Greater Calcutta	1,61,000 KW
Madras (Basin Bridge), Pykara, Mettur, Papanasam and Moyar	2,15,450 KW
Mysore (Jog)	48,000 KW
Travancore	22,500 KW
U. P. (Harduagani), Bahadrabad, Bhola, Sumera & Muhammadpur	40,600 KW



Each symbol indicates major generating plant, hydro and steam, supplying grid transmission lines.

Generating plant of the capacity listed was supplied and installed by A.E.I.

Bhakra Dam Power Plant No. I

A. E. I. are proud to announce that they have been entrusted with the supply of five 100,000 KVA, 166.7 RPM, 11 KV, 50 CPS, 0.9 PF A. C. Generators. When installed these generators will be the largest in India.

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AIX.154

Bhakra Power Plant: AC Generators

In this article the five generating sets with auxiliaries and two transformer units and service bays, control rooms, etc. are described. The stator, the rotor, the bearings, the exciters and the voltage regulators are all discussed.

The Bhakra Power Plant will accommodate 5 generating sets with auxiliaries, two station service transformers, unit and service bays, control rooms, offices, machine shops and general station operating facilities.

The initial installation of generating equipment consists of five 1,00,000 kva vertical shaft generators with direct coupled main and pilot excitors. driven by 1,25,000 H.P. Francis type turbines. Each generator will be operated as a unit with each bank of three 33,333 kva single phase transformer units, connected delta on the low voltage side and wye on the high voltage side with the neutral connected solidly to ground to a current transformer. The main power transformers will be located on the deck adjacent to the power house wall on the tailrace side. Each generator will be operated in parallel with other generators in the power plant on high voltage side of the transformers only. The neutral of each generator will be grounded through a distribution transformer. Circuit breakers will be provided on the high voltage side to connect up the transformers with the switching station.

The station service transformers will be connected across the generator terminals through isolators, and the station service power system voltage will be 3300 volts. The auxiliaries power system will be 415 volts and will comprise of power centres, distribution control centres and feeders to supply A.C. power to station auxiliaries and lighting. Direct current for the operation of some auxiliaries : for control, tripping, and annunciator circuits and for emergency lighting will be supplied and distributed by a 220 volt system.

The power plant is located partly on claystone and partly on sandstone strata. Although the two strata would be treated to react uniformly with respect to settlement, and the base slab and structure be designed with adequate strength, the possibility of a tilt of the installed unit and the power plant structure as one block towards the downstream side through an angle of the order of 0 -6' (six minutes) cannot be excluded.

Generating units and system stability

The generating units and their associated voltage regularators shall be suitably designed to ensure system stability and satisfactory parallel operation with the existing generating units at Jogindernagar, Gangugwai and Kotla Power Houses. The Bhakra Nangal generating systems shall be interconnected. Two synchronous condensers, each of capacity 20,000 kva leading and 10,000 kva lagging are being installed in Delhi Grid Substation.

Type and rating of A.C. Generators

A.C. generators to be furnished shall be of the vertical whaft, water-sheel driven type, each equipped with thrust bearing, two guide bearings, direct connected main and pilot exciters, voltage regulator, excitation cubicle, and a closed system of ventilation with surface air coolers. Parts that are rated equally shall be interchangeable. The rated terminal voltage selected for the most economic and efficient design of generator is 11 kv.

Each generator rating shall be as follows :

1. Capacity, kva.	100,000
2. Power factor	0.9 lagging.
3. Frequency, cycles	50
4. Number of phases	3
5. Speed, r.p.m.	166.7
6. Stator winding connection	star
7. Excitation voltage nominal	250 volts

Principal characteristics

Each generator shall have the following principal characteristics :

1. Normal rated output at 0.9 lagging power factor and at normal rated terminal voltage.	100,000 kva
2. Maximum continuous rating at 0.9 lagging power factor and at normal rated terminal voltage.	115,000 kva
3. Terminal voltage at which the maximum continuous rating must be achieved	11 k.v.
4. Minimum terminal voltage under operating conditions with unloaded system	10% lower than the normal rated voltage.
5. Excitation at maximum leading kva expressed as percentage of that required at normal rated output and power factor	not less than 12%
6. Maximum terminal voltage under operating conditions with fully loaded system	5% higher than the normal rated voltage.
7. Short circuit ratio, on rated kva base not less than	1.2

8. No-load balanced telephone interference factor, not greater than	50
9. No load residual telephone interference factor, not greater than	30
10. Deviation factor of wave form measured in percent on open circuit as rated voltage and frequency not more than	10
11. Efficiency at 100,000 kva, 0.9 power factor lagging, at normal rated voltage and frequency, not less than percent	97
12. Nominal exciter response for main exciter, not less than	0.5
13. Ceiling voltage of main exciter when connected to the generator field and with rated exciter current delivered (80 degrees centigrade), not less than, volts.	300
14. Line charging capacity of the generator when charging a transmission line at rated speed and voltage, without being completely self-excited or unstable, not less than, kva	80,000
15. Flywheel effect (WR^2) of rotating parts of the generator and exciters, not less than, pounds feet squared	60,000,000
16. Direction of rotation	Clockwise.
17. Maximum runaway speed, r.p.m.	333
18. Maximum temperature of cooling water for oil and air cooling system, degrees centigrade.	25
19. Maximum ambient air temperature, degrees centigrade	45

Temperature rise

The maximum temperature rise of the armature and field windings under the worst site conditions shall not exceed 80°C under maximum continuous rating. These shall not exeed 60°C under normal rated output.

In both cases the ambient cooling air temperature is to be taken as 40°C.

Structural details

Each generator shall be for clockwise rotation when looking down on the unit. All parts of the generator are designed and constructed to with-stand safely the maximum stresses under short circuit and runaway conditions.

The generator is designed so that it can be assembled and disassembled with the power house crane for its maximum lift.

The brackets supporting the thrust bearing is to be of massive welded steel construction. The thrust bearing housing is so designed that the entire bearing assembly can be removed in tact with the housing as a unit, after removal of the thrust block. The lower guide bearing bracket or support is designed so that after the bearing is removed the shaft flange will pass through the bracket when the rotor is lifted out and have sufficient clearance. The lower guide bearing bracket is designed so that it can be removed through the stator of the generator. The upper guide bearing is designed so that it will not be necessary to remove the slip rings when dismantling the bearing. The stator and pit beneath each generator is designed to permit the removal of the largest turbine part required to be passed through it when disassembling for repairs.

Each generator housing will be practically of air-tight construction. Adequate relief doors will be provided to relieve internal pressures caused by release of carbon diaoxide without any distortion of the housing.

Stator

Each stator core will be built up with highgrade, non-ageing, thin-laminated silicon steel, each lamination coated on both sides after punching with an insulating varnish or other suitable material to minimise eddy current losses. The laminations shall be adequately keyed or deve-tailed to the stator frame and securely held in place by clamping flanges at each end. To insure uniform tightness of laminations, full and final clamping pressure shall be applied to successive layers of laminations while being stacked; layers to be not more than 16 inches in depth. There will be no perceptible buzzing of limanations during operation.

The stator winding will be star connected. Both ends of conductors of each phase, as nearly equal as feasible be brought out within the generator housing at approved locations and provided with suitable terminals.

Rotor

The rotor will be built in accordance with the best modern practice. The rims of the rotor will be laminated and constructed of steel plates bolted together to make solid structures. The diameter of temporary rim bolts used for constructing rim should preferably be of the same size as of permanent rim bolts. The hubs of the rotor will be attached to the main shaft so that at normal operating speed, and at maximum overspeed, secure attachment will be maintained. The pole pieces will be built up of thin steel laminations secured by rivets of bolts and will be fastened to the rotor rim by means of accurately machined or die-punched dove tails, matching similar slots in the rotor rim and secured firmly in place by means of tapered keys (drive in and drive out keys) and will make adequate bearing on each lamination. The keys will be locked in place on both sides of the rotor rim so as to prevent the keys from coming out in the event they should become loose. If necessary, brackets will be placed between adjacent pole pieces, to brace the windings and prevent them from becoming distorted when subjected to the certrifugal forces due to run-away speed.

Bearings

The generator will be provided with adjustable shoe Kingsbury type or General Electric spring type or English Electric Equalizing Ring type or any other latest standard improved type of thrust bearing.

The thrust bearing offered will be so designed that the loading of each thrust shoe can be checked by means of sensitive indicator but without the use of strain gauges. The thrust bearing will be located above the rotor, and shall have ample capacity to support the combined weight of the rotating parts of the generator, exciters and turbine, including the maximum unbalanced hudraulic thrust of the turbine runner.

Each generator will be provided with two guide bearings, one located above and the other below the rotor. The upper guide bearing will be designed and constructed so that it can be dismantled without disturbing the thrust bearing. The lower guide bearing will be designed and constructed so that it can be removed without disturbing the rotor or stator.

Dam Site as it looks at night during operation

The guide bearings will be of segmental, adjustable oil lubricated, babitted type and adequate provision shall be made for preventing oil or oil vapour from entering the generator cooling system.

Lubrication

The generator will be provided with a complete self contained lubricating system which shall include the latest improvements to eliminate the throwing of oil and escape of oil vapour from the bearings and lubricating system.

Generator cooling

Each generator will be provided with surface air coolers spaced symmetrically around the periphery of the stator frame for a closed recirculating cooling system.

Exciters

Each generator will be equipped with a direct connected, direct current vertical shaft, shunt wound, 250 volts, separately excited, main exciter, mounted on top of the generator and a direct connected, direct current, vertical shaft, compound wound, 250 volt, self excited, pilot exciter mounted on top of the main exciter.

Voltage regulator

The generator will be furnished with an automatic voltage regulator of the latest improved high speed, indirect-acting exciter-field rheostatic type and shall be anti-hunting. It will be responsive to average three phase voltage, will be designed for high speed response excitation, and will be furnished complete with all necessary relays, cross-current and line drop compensators, voltage adjusting rheostat, and all necessary auxiliary appurtenances for parallel operation with other generators, including current and potential transformers.

Exciter field rheostats

The main exciter will be provided with motor operated field rheostat driven by 250 volt, direct current, reversible motor and arranged for remote control from the switch board, and the pilot exciter will be provided with hand-operated field rheostat.

Indicating, recording and protection devices

The generator and its auxiliaries shall be furnished with devices for the indication and recording of temperatures and pressures, and for their protection.

Bhakra power plant generators have to be co-ordinated with the generating units of Nangal power houses at Ganguwal and Kotla. Their principal particulars are given below:—

1.	Number of generators	Four
2.	Type of prime mover	Kaplan turbine. (33,500 H.P.)
3.	Maximum continuous output in KW at 0.88 lagging p.f. of each generator.	24,000
4.	Closed air circuit ventilation with water cooler	
5.	Short circuit ratio	1.8
6.	Synchronous speed in r.p.m.	166.7
7.	Runaway speed in r.p.m.	455
8.	Flywheel effect of turbine runner and generator with exciters and maximum hydraulic thrust in lbs ft	$7\frac{1}{2}$ 18,500,000
9.	Inherent regulation full load at 88%p.f. lagging.	36%
10.	Transient reactance	31.3%
11.	Maximum speed rise:	
	(*i*) at 100% full load thrown off.	23.5%
	(*ii*) at 50% full load thrown off.	9.2%

The generator will be capable of withstanding 3 phase short circuit at its terminals without injury to the steel plate, provided that the duration of such short circuit is not sufficient to cause injurious heating.

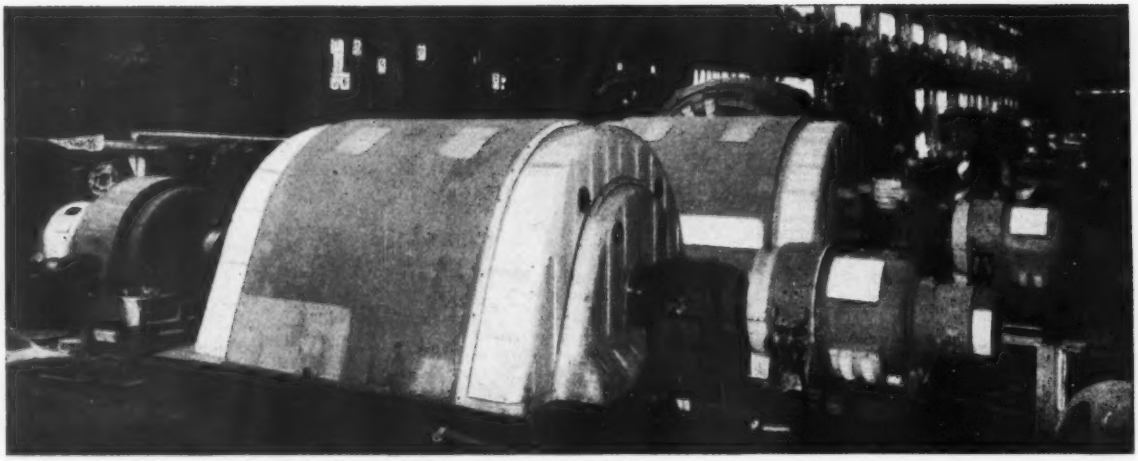
The entire rotor will be designed to withstand safely the maximum runaway speed.

READY TO SERVE

NANGAL—DELHI GRID

OF

PUNJAB GOVERNMENT (INDIA)



20,000 KVA SYNCHRONOUS CONDENSERS

of

Messrs. Mitsubishi Electric Mfg. Co. Ltd., Japan.

Manufacturers' Representatives :

Eastern Equipment & Sales Ltd.

9, BRABOURNE ROAD, CALCUTTA-1.

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Bhakra Nangal Power Generation and Transmission System

Generating stations of the other two sites, namely, Ganguwal and Kotla on the Nangal Hydel Channel are first described. Then the transmission system which includes about 2,300 miles of 220,132,66 and 33 KV extending to Punjab Pepsu, Rajasthan and Delhi is described. The 24 grid sub-stations spread out in all these provinces are then mentioned and a model grid sub-station equipment is described in detail.

The generation of electric power on the Bhakra Nangal system is to take place on the two Power Houses on the Nangal Hydel Channel—Ganguwal and Kotla-and the main Bhakra Power Plant. While the former two generating stations have already been switched on, the latter will be ready for being commissioned in 1959-60.

Each of the Nangal Power Houses are equipped with two generating units—each unit comprises one 33,500 H.P. 167 RPM, vertical Kaplan turbine, coupled to a 24 M.W.AK. generator along with other associated equipments. Each generating unit is connected to a 27 M.V.A step up transformer for stepping up the voltage from 11 KV to 132 KV for feeding the transmission system. The two power houses are inter-connected to a double circuit 132 KV tie line. Power House No. 2 (Kotla) is controlled from Power House No. 1 through remote supervisory control. An 11 KV interconnecting feeder is provided between the two power houses for interchange of auxiliary power, for operating the local auxiliaries.

The transmission system is designed with two fold consideration that initial costs are as low as possible, and yet the system is flexible so as to enable increase in its capacity later on with the development of load.

Transmission System

The power generated at the Nangal Power Houses and later on at Bhakra, will be transmitted to the load centres in the States of Punjab, Pepsu- Rajasthan, Himachal Pradesh, and Delhi by a vast net work of extra high tension transmission lines. The total mileage of the 220, 132, 66 and 33 KV transmission lines will be about 2300. The project also provides for about 800 miles of 11 KV lines and a huge net-work of 400 volt lines for distribution of power from the grid-substations to the consumers in the Punjab, for 225 miles of 11 KV lines in Pepsu, and for 140 miles in Rajasthan. The transmission lines have been so planned and the location of grid substations so selected that practically no place in these States will be more than 30 miles away from the nearest grid-substation.

The transmission system has been designed with the dual consideration that while initial costs should be kept as low as possible, the system should be flexible enough to enable its capacity being increased later on at very little extra cost. An outstanding feature of the transmission system is the use of a transmission voltage of 220 KV between Nangal and Delhi. Such high voltage is being used in India for the first time. Some of the important transmission lines are briefly described below

32/220 KV Nangal-Delhi Line

This is a double circuit line, 195 miles long, and connects Nangal Power House No. 1 at Ganguwal with Delhi. This is the main trunk line of the transmission system, and it will also serve as connecting link between the Delhi Power System and the Nangal Power System. This line has been designed for an ultimate transmission voltage of 220 KV although, in the initial stages, it will operate at 132 KV. Operation at 220 KV will be resorted to when the development of load will so warrant. This line will have grid substations at Dhulkote (Ambala), Panipat, and Delhi.

132 KV Lines

There will be a double-circuit line from Nangal to Ludhiana (74 miles) where it will bifurcate into two single-circuit lines : one going from Ludhiana to Jullundur (38 miles) for inter-linking with the Uhl River Scheme and the other will link Ludhiana with Sri Ganga Nagar in Rajasthan, with intermediate grid sub-stations at Moga and Muktsar. The length of this line from Ludhiana to Moga is 44 miles, from Moga to Muktsar 50 miles. Another 132 KV line will take off from 132/220 KV grid substation at Panipat for Hansi (70 miles) and will further proceed to Hissar, Rajgarh, and Rattan Garh (Rajasthan), comprising a total length of 116 miles.

66 KV lines

A double circuit 66 KV line (23 miles) takes off from Dhulkote (Ambala) for Chandigarh, from where a single circuit line will continue up to Simla (47 miles) with intermediate grid substations at Surajpur and Solan. Another single circuit 66 KV line connects Dhulkote (Ambala) with Nabha (45 miles), with intermediate substations at Rajpura and Patiala. Another 66 KV single circuit line has been run from Panipat for Abdulapur-Jagadhri (61 miles)

with intermediate grid substations at Karnal and Indri. One 66 KV line (85 miles) will connect Bikaner with Ratangarh, both in Rajasthan. Another similar line (63 miles) will connect Ganganagar and Muktsar.

33 KV Lines

A large number of 33 KV transmission lines, totalling about 1360 miles, will take off from the various 220, 132 and 66 KV substations mentioned above and will feed about 80 grid substations of 33 KV. 11 KV lines will carry electricity from these grid substations to the urban and rural areas for distribution to consumers.

System Control

The essential requirements for the control of a large network of transmission lines are an efficient telephone system and a central control office. Tele-communications have been provided on the entire system. Communications can thus be established with any point on the huge net work. The Central Control Office is proposed to be located at the Ganguwal Power House. The load conditions at various places will be automatically telemetered in this control office. The Controller will thus be able to regulate the system-conditions according to requirements.

Grid-substations

The transmission net-work described above will feed 24 grid substations of voltages ranging between 220 KV and 66 KV, and about 80 substations of 33 KV. All these substations will serve the following major towns and the surrounding rural areas in the States of Punjab, Pepsu and Rajasthan :

The Punjab

Ambala District :
Ambala City, Ambala Cantt., Chandigarh, Rupar, Kharar, Kurali, Morinda, Manimazra, Kalka, Simla, Naraingarh, Brara, Sadhura, Abdullapur, Jagadhri, Chhachrauli, Buria, Shahzadpur, Raduar, Shahbad.

Karnal District :
Panipat, Karnal, Indri, Pipli, Nilokheri, Kurukshetra, Thanesar, Kaithal, Gharaunda, Ladwa, Jandola.

Rohtak District :
Sonepat, Rohtak, Sampla, Kharkhoda, Gohana, Jhajjar, Bahadurgarh, Smalkha, Ganaur.

Hissar District :
Hansi, Hissar, Bhiwani, Dabwali, Jakhal, Tohana, Uklana, Barwala, Fatehabad, Sirsa.

Gurgaon District :
Gurgaon, Sohana, Rewari, Palwal, Faridabad, Ballabgarh, Farrukhnagar.

Ferozepur District :
Ferozepur city, Ferozepur Cantt. Zira, Talwandi, Dharamkot, Giddarbaha, Jallalabad, Guru-Har-Sahai, Malout, Abohar, Muktsar and Fazilka.

Jullundur District
Jullundur City, Jullundur Cantt. Nakodar, Shankar, Mehatpur, Nawanshahr, Rahon, Banga, Nurmahal, Rurka Kalan, Mahal, Barapind, Paddi Jagir, Sherpur, Pragpur, Badala, Kartarpur, Adampur, Alawalpur, Goraya, Phillaur.

Hoshiarpur District :
Bajwara, Hariana, Gardhiwala, Mukerian, Dasuya, Urmar Tanda, Miani, Garh Shankar, Una, Mahilpur and Anandpur.

Ludhiana District :
Ludhiana, Bassian, Raikote, Jagraon, Samrala, Khanna, Machhiwara, Nandpur, Sahnewal and Kila Raipur.

P.E.P.S.U.

Patiala District :
Patiala, Nabha, Sangrur, Rajpura.
Fategarh District :
Sirhind, Bassi, Amloh, Gobindgarh, Pial, Doraha.
Kapurthala District :
Kapurthala, Phagwara, Hadiabad Sultanpur.
Bhatinda District :
Bhatinda, Goniana, Faridkot, Kot Kapura, Jaito, Masa, Budlada, Breta, Maur.
Mohindergarh district :
Dadri.

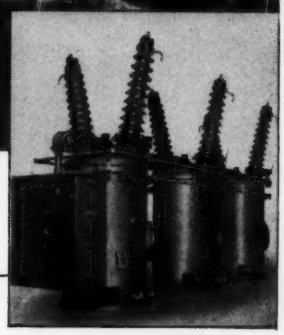
Rajasthan

Sri Ganga Nagar Area
Sri Ganganagar, Karanpur, Mesri Singhpur, Gajsinghpur, Prithvi Rajpur, Rai Singhnagarh, Bijeya Nagar, Suratgarh, Anupgarh, Pili Bangha, Sadul Garh, Sadulshahr, Chotala Road, Hanumangarh.

Rajgarh Area
Bhadra, Nohar, Rajgarh, Tara Nagar, Sardarshahr, Ghuru, Monsar, Deepalsar, Ratanagarh, Taluchapar, Bidasar, Sandwa, Sujangarh, Jaswantgarh, Bissau Ramgarh, Jhunjhuna, Nawalgarh, Khetri, Lachhmangarh Sikar, Fatehpur, Pillani, Surajgarh, Cherwawa.

As a typical instance details are given for the grid substation equipment proposed for the Ambala station. These are only typical and variations are not to be excluded.

Generating Unit in Ganguwal Power House



BHAKRA NANGAL

POWER GRID

Eleven Outdoor Sub-Stations...

are being completely equipped with 'English Electric' Power Transformers, associated Switchgear and control equipment. The illustration above shows one of the 132 kV Oil Circuit Breakers supplied for Hansi sub-station.

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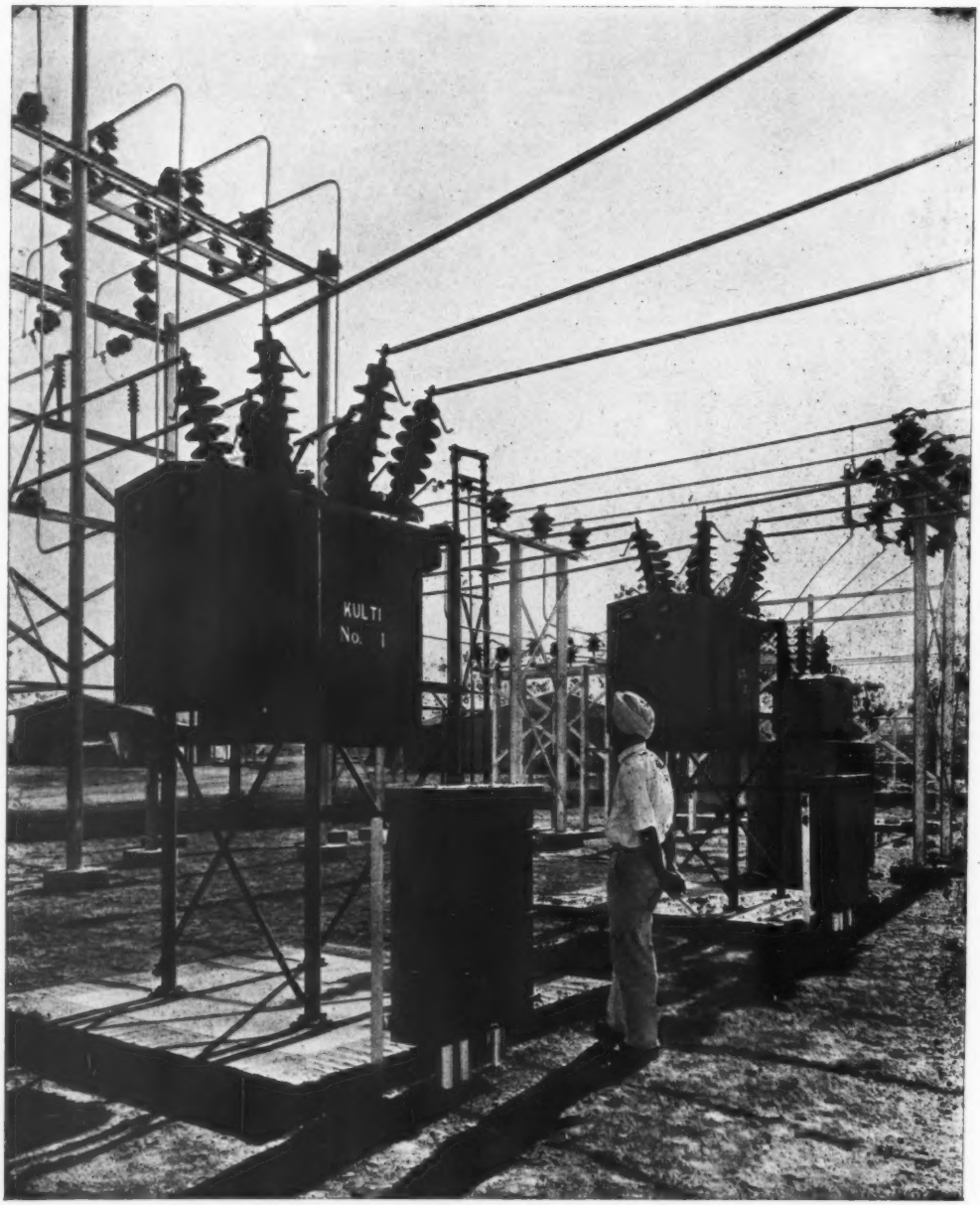
REYROLLE SWITCHGEAR



REYROLLE TYPE "ORT2" 33000 VOLT SWITCHGEAR. SIMILAR TO THAT SUPPLIED FOR SUBSTATIONS ON THE NANGAL PROJECT.

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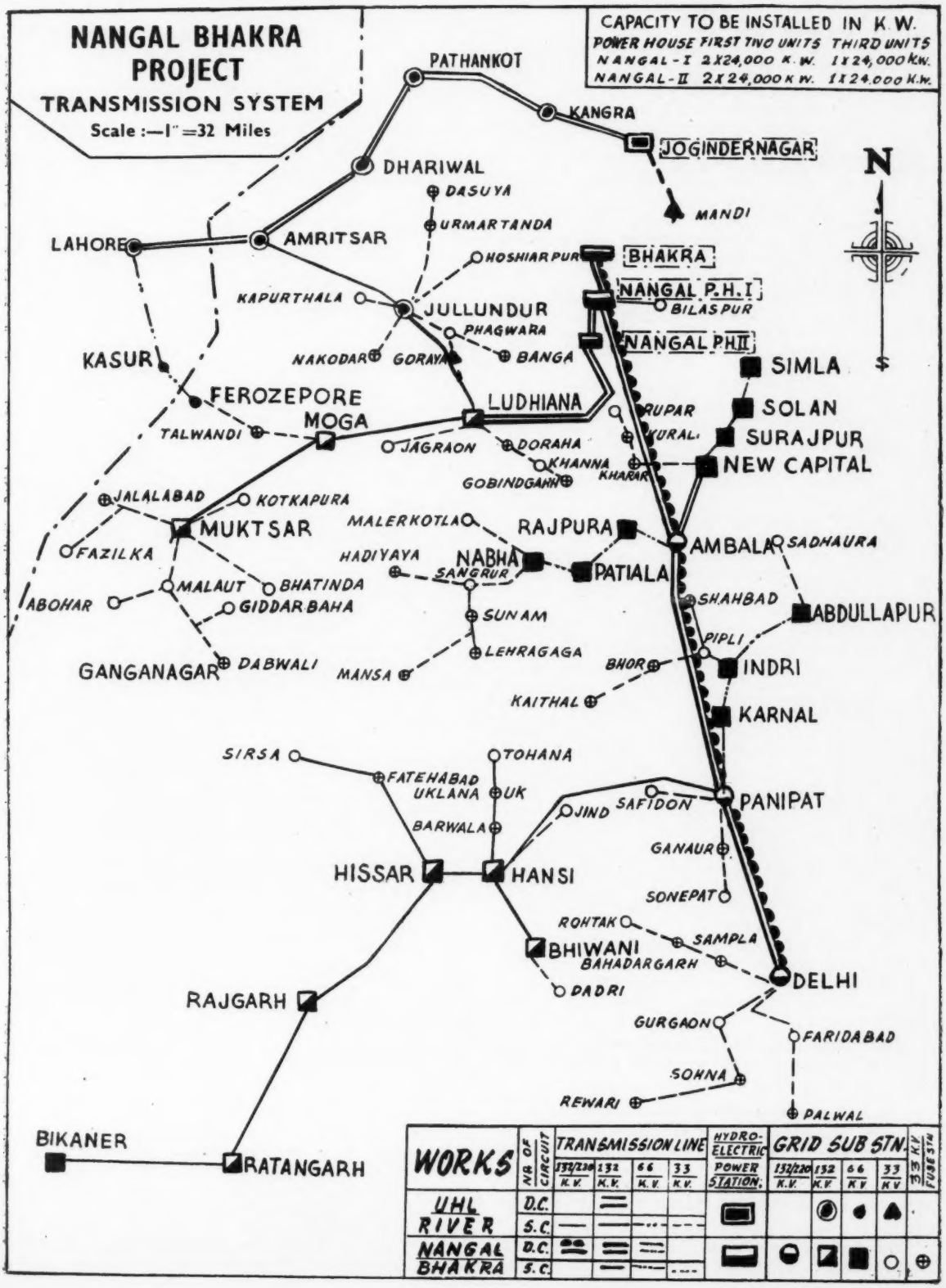
NANGAL BHAKRA PROJECT
TRANSMISSION SYSTEM
Scale :—1" =32 Miles
CAPACITY TO BE INSTALLED IN K.W.
POWER HOUSE FIRST TWO UNITS THIRD UNITS
NANGAL-I 2X24,000 K.W. 1X24,000 K.W.
NANGAL-II 2X24,000 K.W. 1X24,000 K.W.
N
PATHANKOT
KANGRA
JOGINDERNAGAR
MANDI
DHARIWAL
DASUYA
URMARTANDA
LAHORE
AMRITSAR
HOSHIARPUR
BHAKRA
NANGAL P.H.I
BILASPUR
KAPURTHALA
JULLUNDUR
PHAGWARA
NANGAL PH II
KASUR
NAKODAR
GORAYA
BANGA
SIMLA
FEROZEPORE
LUDHIANA
RUPAR
SOLAN
MOGA
KURAL
SURAJPUR
TALWANDI
JAGRAON
DORAHA
KHANNA
KHARAR
NEW CAPITAL
GOBINDGARH
JALALABAD
KOTKAPURA
MUKTSAR
MALERKOTLA
RAJPURA
AMBALA
SADHAURA
FAZILKA
HADIYAYA
NABHA
PATIALA
SANGRUR
MALAUT
BHATINDA
SHAHBAD
ABDULLAPUR
ABOHAR
GIDDARBAHA
SUNAM
PIPLI
LEHRAGAGA
BHOR
INDRI
GANGANAGAR
DABWALI
MANSA
KAITHAL
KARNAL
SIRSA
TOHANA
FATEHABAD
UKLANA
UK
SAFIDON
PANIPAT
BARWALA
JIND
GANAUR
HISSAR
HANSI
SONEPAT
ROHTAK
SAMPLA
BHIWANI
BAHADARGARH
DELHI
DADRI
RAJGARH
GURGAON
FARIDABAD
SOHNA
REWARI
PALWAL
BIKANER
RATANGARH
WORKS
NO OF CIRCUIT
TRANSMISSION LINE
132/220 K.V.
132 K.V.
66 K.V.
33 K.V.
HYDRO-ELECTRIC POWER STATION.
GRID SUB STN.
132/220 K.V.
132 K.V.
66 K.V.
33 K.V.
33 KV FUSE STN.
UHL RIVER
D.C.
S.C.
NANGAL BHAKRA
D.C.
S.C.

1. *Transformers*
   (*i*) 2-10 MVA, 132/66 KV
   (*ii*) 2-4 MVA, 66/11 KV
   (*iii*) 2-100 KVA, 11/0.4 KV Service Transformers
2. 220 *K. V. Switchgear*
   (*i*) Oil Circuit Breakers
   7-800 amps, 230/196 KV, 3 pole, single throw oil circuit breakers for outdoor service complete with accessories.
   (*ii*) Disconnecting switches.
   (*a*) 16-1200 amps, 230/196 KV, 3 pole single throw outdoor disconnecting switches.
   (*b*) 5-1200 Amps, 230/196 KV, 3 pole single throw outdoor disconnecting switches with grounding blades.
   (*iii*) Lightning Arresters.
   15—Station type auto-valve single phase, single pole, self-supporting lightning arresters for 132 KV grounded neutral system.
   (*iv*) Coupling capacitor, line traps and current transformers.
   (*v*) 1 set—220 KV Bus and connection material and line dead ending material.
3. 66 *K.V. Switchgear*
   (*i*) Oil Circuit Breakers.
   7-600 amps, 69 KV, 3 pole, single throw oil circuit breakers for outdoor service complete with accessories.
   (*ii*) Disconnecting Switches.
   (*a*) 20—600 amps, 69 KV, 3 pole, single throw outdoor disconnecting switches.
   (*b*) 3—600 amps 69 KV, 3 pole, single throw outdoor disconnecting switches with grounding blades.
   (*iii*) Lighting arresters.
   9—Station type auto-valve single phase, single pole lightning arresters for 66 KV grounded neutral system.
   (*iv*) Instrument Transformers.
   (*a*) 12—outdoor oil immersed, 69000/115 volt 50 cycles potential transformers
   (*b*) 1 set—High voltage potential fuses.
   (*c*) 2—outdoor current transformers ratio 150/5 amps.
   (*d*) 2—outdoor current transformer, ratio 75/5 Amps.
   (*v*) 1 set—66 KV bus and connection material and line dead ending material.
4. 11 *K.V. Switchgear*
   15—metal clad switchgear units for the control of 11 KV incoming and outgoing feeders complete with equipment.
5. *Duplex Switchboard*
   (*a*) 5—Duplex type switchboard panels for the control of 132 KV circuits complete with equipment.
   (*b*) 4—Duplex type switch board panels for the control of 66 KV circuits.
6. *D.C. Equipment*
   220 volt D.C. equipment including battery, rectox battery charger, motor generator set and control panel.
7. *Grounding Material*
8. *Panel Board*
   1—outdoor, weather proof, no fuse panel board for transformer and O.C.B. heaters.
9. 400 *Volt Switchgear*
   1—400 volt switchgear for power centre.
10. Conduits, cables and miscellaneous hardware fittings.
1. Carrier relaying equipment.
2. Oil filtration set complete with tanks etc.
3. Fire extinguishing equipment.
4. Metering equipment.

(*Continued from page* 57)

Gates and Valves

Electrical machinery, controllers and conductors are also specified.

Hoist Shaft Draw Bridges

These consist of two draw bridges complete with locking devices and two 2-ton chain pulley blocks. The two draw bridges are provided at EL 1333 and EL. 1433—the gate gallery elevations. These draw bridges shall mainly be used for handling the equipment for 96″ jetflow gates and other accessories of gate galleries.

The bridge is hinged on one side and is raised by a chain hoist fastened to an anchor at the ceiling of the adit and is secured in its raised position by a special looking device. When lowered transfer cars can pass over it.

After the field assembly a coat of red lead shall be applied to these bridges followed a by suitable machinery paint.

Steel Penstocks for Bhakra Dam

Some important points regarding the fabrication and installation of fiftten feet diameter penstock through the left non overflow section and subsequently through the right non overflow section are worthy of note. In all there will five penstocks on the left and five on the right.

The steel plates for penstocks is to be all imported. Arrangements have been made for its being rolled to the required curvature and levelled for welding in the field. There will be stiffener rings round the penstock in order to resist the stresses and also to enable proper embedment in the concrete. All the forces of penstock sections will have a maximum of two longitudinal joints. The length of each force will be 10 feet. Aminimum of 6 feet is however, acceptable. The longitudinal joints of adjoining forces of the penstock sections will be at 45 degree from the vertical centre line. These will be staggered 90 degrees.

For the pending the rolling of the plates to the exact curvature, a bending roll suitable for handling two inch thick plate has been obtained by the project authorities. The penstocks will have structural steel support and anchors and strusts. The assembled penstock sections will be welded in the field.

The fabrication of the penstock sections will be done in accordance with section W of the 1951 edition of the API ASE Code for the design, construction, inspection and repair of unfired pressure vessels for petroleum liquid and gases. These codes are according to the American Petroleum Institute and American Society of Mechanical Engineers.

The field welding of penstocks will be a very tricky job and for this purpose highly qualified welding operators are proposed to be engaged. There will be radiographic inspection of welds in order to ensure their soundness. The erection and installation of the penstocks will be done departmentally.

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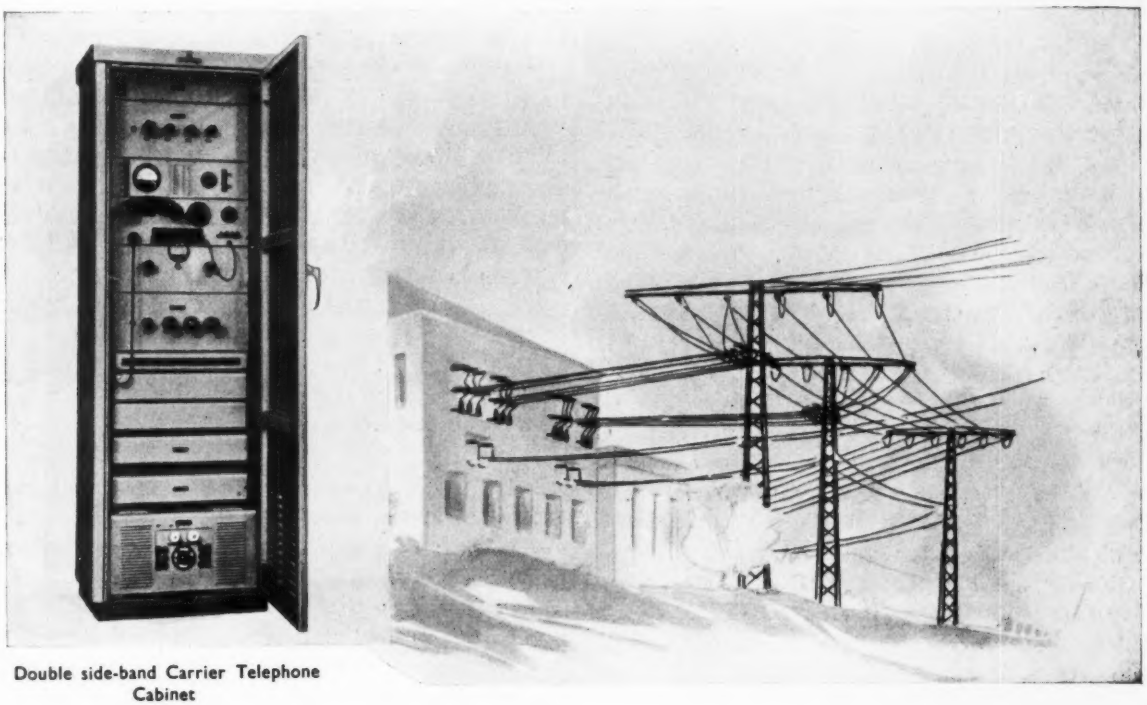

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Bhakra Canals

The irrigation requirements of East Punjab and Rajasthan are first described and a historial review of past plans of irrigation is given. Then the details of the irrigation aspects of Bhakra Project are given. The remodelling of Rupar Head Works and of the Sirhind Canal and the construction of the Bhakra Canal System as well as the Bist Doab Canal are then dealt with at length.

The Bhakra Canals system was planned to cater the irrigation requirements of the arid and dry areas in Hissar district and adjoining areas of Rohtak and Karnal Districts and Bikaner State (now Rajasthan) which are proverbially famine stricken. The average annual rainfall of this area does not exceed 13 inches of which only 10 inches fall in summer. This is quite insufficient for successful farming. Well irrigation is also very difficult due to very low water table. Conditions of scarcity of water in the tract are simply appalling. A perusal of the reports of the Famine Commission shows repeated instances of famine for the last 100 years and continued loss of human and cattle lives. In 1899-1900 the total loss of cattle in the tract was 12,23,000. It was estimated that in the two years following 1895, 92% of the plough and well cattle in the Hissar tract perished. Only recently this tract was in the grips of a fodder famine and even with the modern transport facilities loss of cattle could not be prevented.

Although the necessity of providing irrigation facilities to this area has been long felt, it has not been possible to provide irrigation from Sutlej and Yamuna, as the run-of-the-river supplies have been already exhausted. The only other alternative under consideration has been the use of stored supplies of the Sutlej. The idea of having a dam at Bhakra was first conceived as early as 1908. The first project was prepared in 1911 which was followed by subsequent Projects in 1919, 1934 and 1949-50. In spite of the dire necessity and extreme misery of the population of this area, in undivided Punjab, preference was given to other projects in the West Punjab and the tract continued groaning under famine conditions.

The Project will usher in an era of great prosperity in transforming wide barren expanses of the countryside into rich crop lands and smiling gardens.

The Bhakra Canals system will be utilizing a discharge of about 18,000 cusecs. The length of Main canals and branches is 690 miles and that of distributaries is 2100 miles. The new areas to be served by this system are approximately38,00,000 acres in the Punjab, 10,87,000 acres in Pepsu and 9,20,000 acres in Rajasthan totalling in all about 58,00,000 acres. Supplies will be increased on Sirhind Canal in an area of over 20,00,000 acres in Punjab and 16,00,000 acres in Pepsu. The total area benefiting frrom the Project is nearly 10 millions acres.

The Bhakra Canal system comprises the following parts :

(*i*) Remodelling Rupar Head Works ;
(*ii*) Remodelling Sirhind Canal ;
(*iii*) Bhakra Canal System ;
(*iv*) Bist Doab Canal.

Remodelling Rupar Head Works

This is the oldest Headworks in the Punjab having been completed in 1873. It consist of 10′ wide weir crest mounted by a battery of dropping steel shutters 4′ wide and 6′ high for ponding up the river water. From the left bank there takes off the Sirhind Canal with a capacity of 9040 cusecs.

The remodelling of Rupar headworks has been necessitated on account of the following reasons :

(*a*) The capacity of Sirhind canal was to be raised from 9040 cusecs to over 12,000 cusecs. To pass the additional discharge through the present regulator, it was necessary to raise the Pond level by 2.0′.

(*b*) A new Canal, named Bist Doab, with a discharge of 1800 cusecs was to take off from the right bank necessitating construction of undersluices on the right side.

(*c*) The old Headworks was designed to pass the maximum discharge of 2,32,000 cusecs but actually a record flood of 4,90,000 cusecs passed the Headworks' in the year 1947.

A number of alternative proposals were considered and the final proposal was to convert the old shutter weir into a gated barrage. This consisted of 32 bays each of 60 ft. clear span in the weir portion, 2 bays each of 60 ft. clear span with 7 ft. thick piers and 2 bays each of 27.5 ft. clear span with 5 ft. thick pier in the right undersluices. There are two fish ladders 14 ft. and 10 ft. wide on right and left sides respectively. An arterial road bridge is combined with the barrage which connects Chandigarh and Rupar with Jullundur, Hoshiarpur and Pathankot.

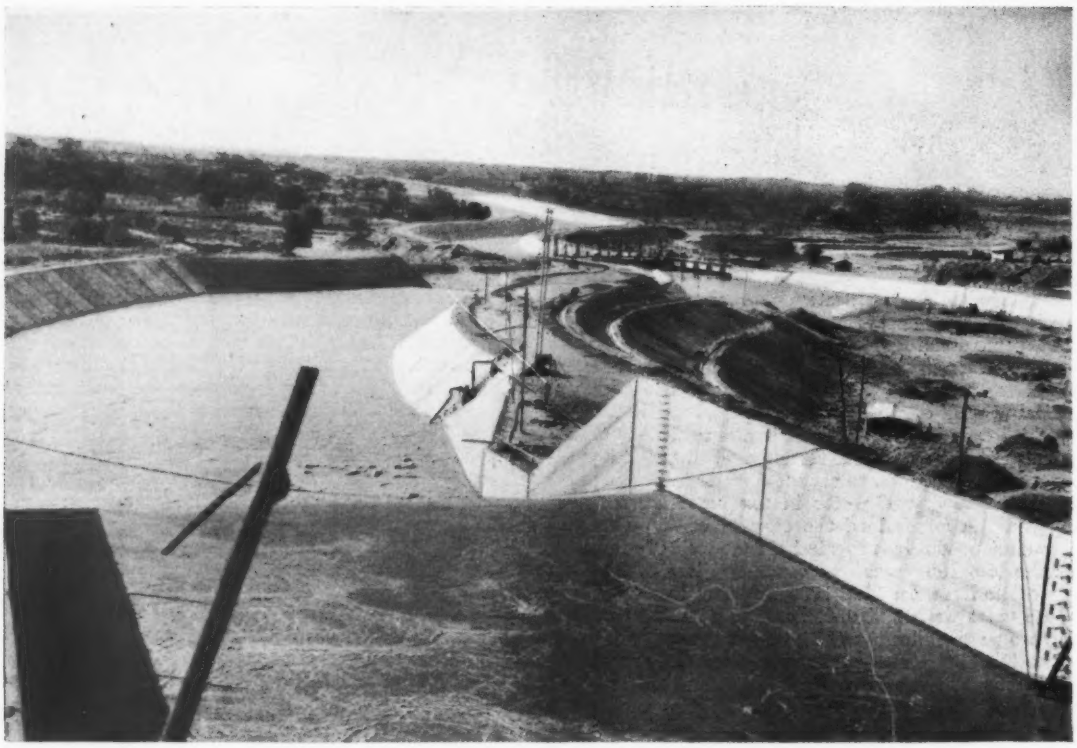
Remodelling Sirhind Canal

This Canal had to be remodelled to take up an extra discharge of over 3500 cusecs for bringing under Irrigation certain areas which orginally coiuld not be brought under irrigation due to shortage of supply, and to supply water to the area on Grey canals in Ferozepur district which will be deprived of inundation supplies from the river after the construction of the Bhakra Dam. The old channels were enlarged for increased supply and a new channel namely Sidhwan branch had been constructed to serve the area served from Grey canals.

New Distributaries and minors on Sirhind Canal

Sidhwan Branch :

It is a 58 miles long unlined channel with a discharge of 1751 cusecs and bed width and depth at head as 96 ft. and 6.3 ft. respectively.



A view of the By-pass Channel at Ganguwal

Golewala and Mudki Disty : system

This system comprises of a total discharge of 539 cusecs.

Bhakra Canals

The Bhakra Main line takes off from the tail of the Nangal Canal at Rupar and is designed for a full supply discharge of 12,457 cusecs. From Rupar, passing through the enclaves of the State of Pepsu, its proceeds almost straight to Tohana situated on the border of Hissar District.

The Main Line absorbs the existing Ghaggar and Choa Brranches, and the Patiala Navigation channel of the Patiala Branch of the Sirhind Canal. This is a convenient arrangement as it releases corresponding capacity of the Sirhind Canal to accommodate the additional supply to be run.

In addition to direct distributaries of an aggregate capacity of 1226 cusecs, the following branches take off from the Bhakra Main Line, Bhakra Main Branch and from the Narwana Branch :

Sr. No. Name of Branch	*R. D. of off-taking point and name parent channel.*		*A. F. S. of discharge in cnsecs. (approx.)*
1. Narwana Branch	157,000	Bhakra Main Line	4,459
2. Ghaggar Branch	204,000	-do-	1,433
3. Choa Branch	270,210	-do-	314
4. Bhakra Main Branch	538,730	-do-	5,069
5. Fatehbad Branch	538,730	-do-	1,707
6. Ratia Branch	2,633	Bhakra Main Branch	671
7. Rori Branch with Ottu Feeder	223,928	-do-	1,030
8. Karnisingh Branch	449,500	-do-	448
9. Sadul Branch	449,500	-do-	1,244
10. Barwala Sub Branch		Narwana Branch	824

The Bhakra Main Line, Main Branch, Narwana, Karnisingh and Sadul Branches are lined channels and the rest unlined.

The Narwana Branch would irrigate the Samrala-Rajpura tract (No. 6), Patiala tract (No. 7) Kaithal Pehowa tract (No. 8), Pepsu area between Ghaggar and Dhamtan distributary (tract No. 9), Barwala extensions (tract No. 10 and 11) and the existing area of the Sirsa Branch from Habri head to the head of Gorakhpur distributary. The Sirsa Branch from head to R.D. 88,000 has been renamed as Narwana link.

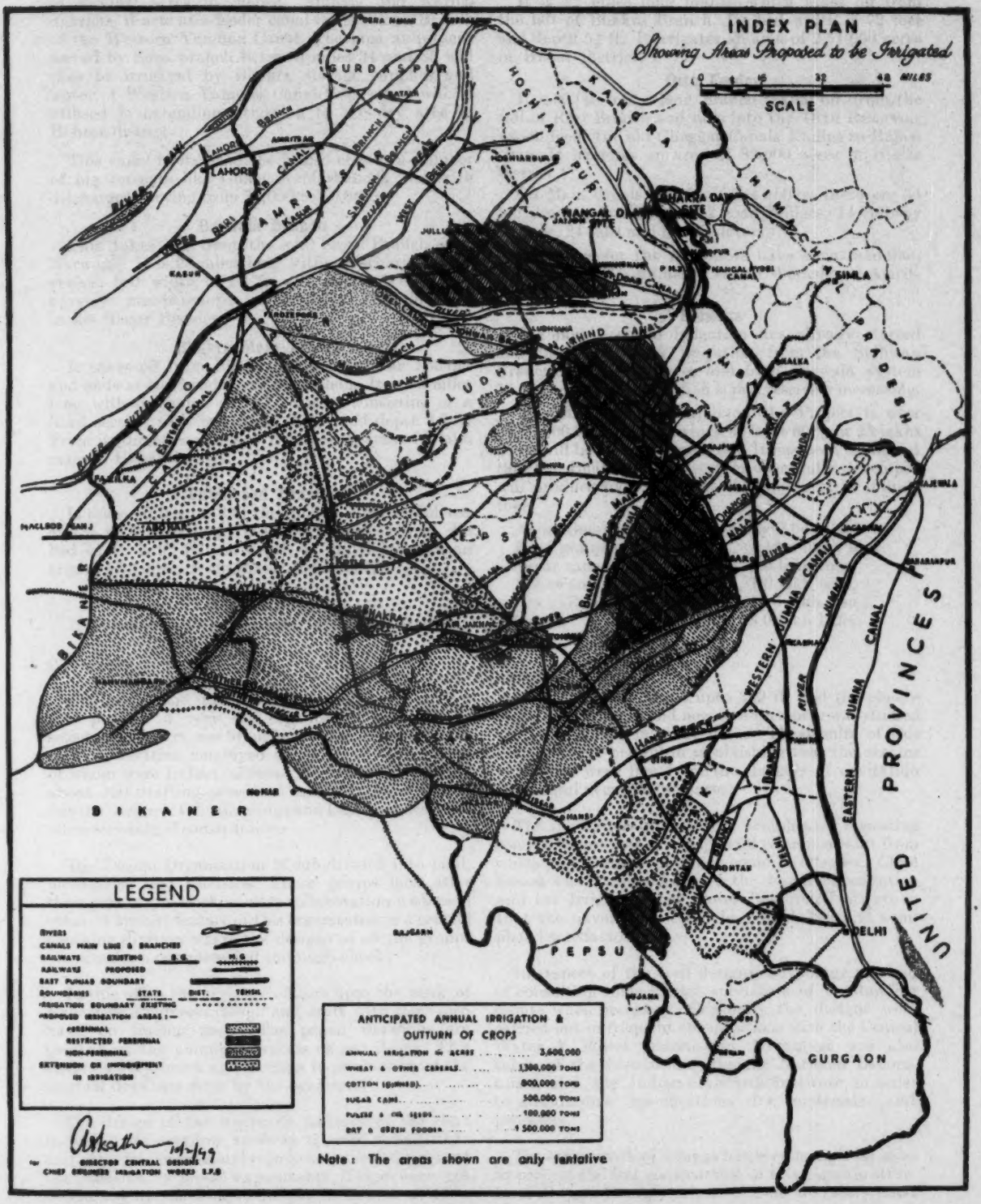
The Fatehabad and the Bhakra Main Branches take off from the tail of the Bhakra Main Line and through further branches and distributaries, irrigate the Hissar district, Dhudal tract of Pepsu and Rajasthan areas.

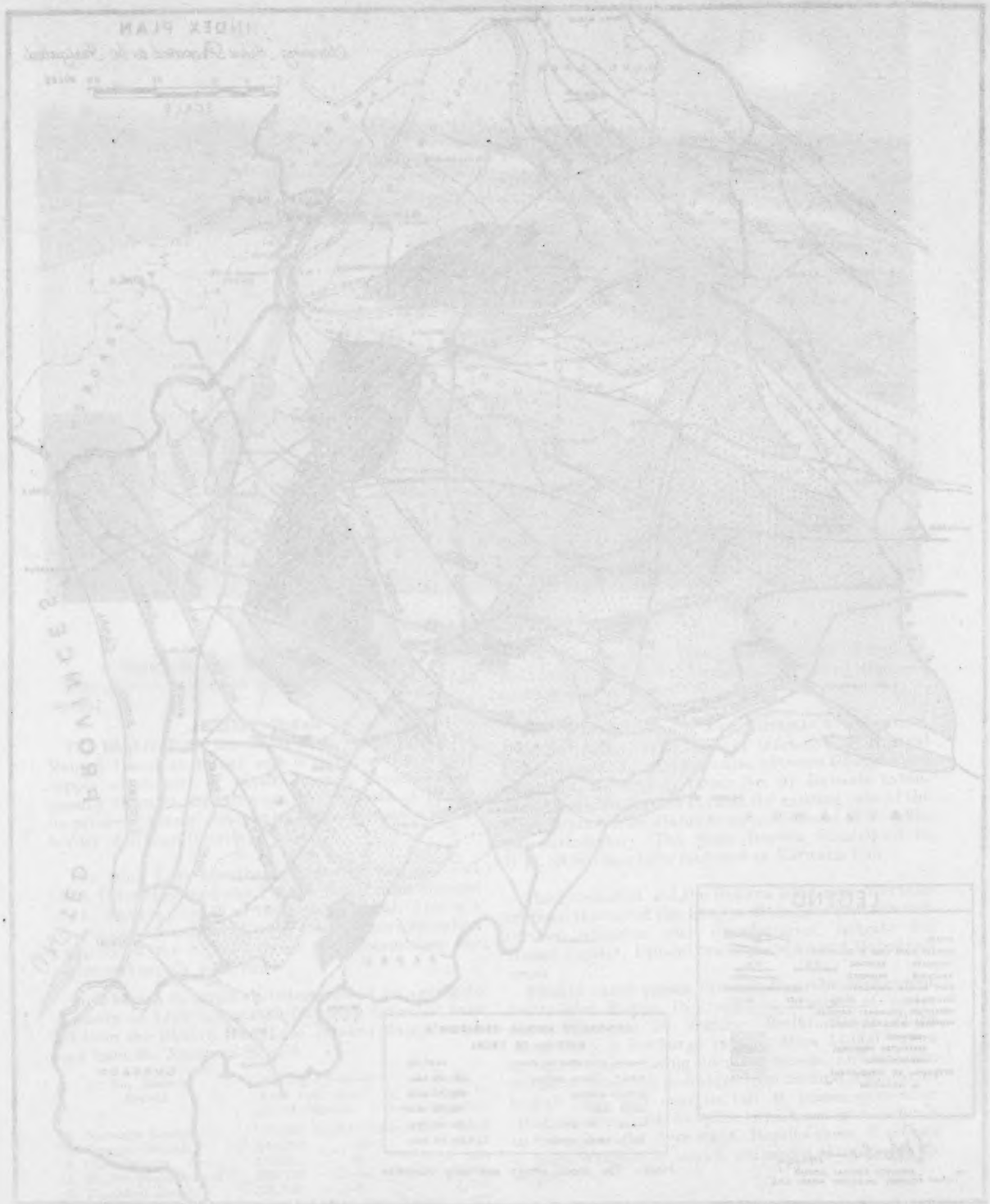
Bhakra canal passes through the submountaneous tract near Rupar. It crosses a number of major natural torrents like Sughrao, Budki, Siswan which often carry a discharge ranging from 14,000 cusecs to 70,000 cusecs during the rainy season. Lower down, it has to cross big drainages like Sirhind and Jhambowali Choe and near its tail, it passes over river Ghaggar along with its spills, which are more difficult to cross than the river itself. Besides these, it crosses a large number of small drainages throughout its length.

Narwana Branch

It takes off from R.D. 1,58,000 left of Bhakra Main Line and is 64 miles long. It tails into existing Sirsa Branch. It is a line channel with bed width 30 ft.

Facing page 74





and depth 18 ft. In addition to irrigating new area of 428,000 acres in Pepsu, Ambala and Karnal districts, it acts as a feeder canal for the Sirsa Branch of the Western Yamuna Canal. The area at present served by Sirsa branch between miles 34 and 85 will thus be irrigated by Bhakra storage supplies and water of Western Yamuna Canal thus saved will be utilised in extending irrigation to the dry area in Rohtak district.

This canal in its head reach also crosses a number of big torrents like Ghaggar, Markanada etc. with discharges varying from 75,000 to 50,000.

Barwala Branch

This takes off from the old Sirsa Branch near Narwana. It is 28 miles long with a discharge of 836 cusecs, bed width of 65 ft. and depth five feet. It provides non-perennial irrigation to 2,60,000 acres in the Hissar District.

Bhakra Main Branch

It takes off from Bhakra Main Line near Tohana and ends at the boudary of Rajasthan. It is 90 miles long with discharge of 5,055 cusecs consisting of a lined section with bed width 30 ft. and depth 18 ft. From its direct channels, it irrigates an area of 3 lakh acres in Hissar district.

Fatehabad Branch

It takes off from tail of the Bhakra Main at Tohana and is 60.3 miles long. It is an unlined channel. Its bed width is 92 ft. and depth 6.5 ft. It irrigates an area of 4,52,000 acres in Hissar district.

Ratia Branch

It is also an unlined channel. Its length is 28 miles.

Rori Branch

It is 22 miles long branch which takes off from the left of Bhakra Branch. Its bed width is 72 feet and depth $5\frac{1}{2}$ ft. It irrigates an area of 2,51,000 acres in Hissar district.

Ottu Feeder

It is a 145 miles long branch taking off from the tail of Rori Branch and tails into the Ottu Reservoir which feeds the old Ghaggar Canals leading to Rajasthan. It irrigates an area of 83,000 acres in Hissar district.

On Main canals and branches above, there are 34 big drainage crossings, 232 road bridges, 14 railway bridges, 24 falls and 66 regulators.

The gates for the regulators have been manufactured in the Government Central Workshops, Amritsar.

Benefits

The non-perennial irrigation has already started and in Kharif 1952 irrigation from the Sidhwan Branch was 49,652 acres and from Barwala system 75,224 acres. The irrigation is progressively increasing.

The total area of Punjab on the Project is over 38,00,000 acres, out of which at least 60% or 23 lakhs acres will be irrigated annually. It has been estimated that the Bhakra Canals system when fully developed will produce food grains to the tune of 1.13 million tons.

Approximate figures crop-wise will be as below :

Food grains	1.13 million tons.
Sugar cane	5.0 lakh tons.
Pulses and oilseeds	1.0 lakh tons.
Dry and green fodder	15.0 lakh tons.
Cotton	8.0 lakh bales.

(*Continued from page* 77)

Bhakra Dam Administration

The job of the designs was a colossal one but for this purpose a very big organisation manned by selected engineers was brought into being. At its peak this organisation employed about 85 engineers most of whom were Indian officers. They were assisted by about 150 drafting personnel and they have turned out the designs of the drawings and kept pace with the office schedule of construction.

The Design Organisation is sub-divided into civil, mechanical and electrical. These groups look after their part of the work in close collaboration with each other. A special feature of this organisation is a central checking division where the designs of all the groups are sent for a complete and thorough check.

In this office the engineer officers upto the rank of Executive Engineers design and draft with their own hand on tracing paper. The pencil drawings are printed on the ammonia process on azo sheets. This ensure a very quick and flawless re-production of the original drawings done by the egnineers.

The design of the hydraulic features of the dam including the overflow, spillway tunnels, river outlets and gates for controls and regulations, needed frequent confirmation by model experiments. These were got conducted by the Punjab Irrigation Branch at their Hydraulic Stations at Malikpur and Amrtisar and the research carried out involve the use of pressure tanks to simulate heads upto 360 ft. and the phenomena of cavitation and negative pressures was studied at these models in great detail. The results of this research were helpful in establishing that the designs taken out were free from the dangers of cavitation or harmful negative pressures.

The simulation of models of complicated operating conditions provide a most useful reference point from which improvement in design could be effected. Close liaison was observed between the design organisation and the Irrigation and Power Research Institute so that the novel work could be undertaken and completed satisfactorily.

In respect of the civil designs, advantage was had of consulting some foreign specialists of outstanding repute when necessary. Originally the designs were carried out in frequent consultations with the Central Water & Power Commission. Advantage was also taken of the Institutions like the National Laboratories and the Indian Standards Institute, in order to standardize specifications for materials and processes.

The entire work of designs has been completed so as to prompt the fast construction of this gigantic structure. Design changes when become necessary that they are promptly carried out on the merits of each case.

Bhakra Dam Administration

The administrative set-up of the Bhakra Nangal Project is extremely instructive. It is based more on the idea of "functional control" instead of "regional control". The following wings of the project are then described : Directorate of Bhakra Dam Designs, Construction Directorate and Directorate of Inspection and Control. The role of the foreign specialists is clearly defined.

The Bhakra Dam Administration has been organized under a system of "Functional Control" instead of "Regional Control". The functions have been centralised into the following organization :

1. Directorate of Bhakra Dam Designs.
2. Construction & Plant Design Directorate.
3. Directorate of Inspection and Control.
4. Bhakra Dam Circle.

Bhakra Dam Designs Directorate

This Directorate has been set up at Delhi under a Director of Superintending Engineer's rank. The work is divided in 6 main groups headed by Deputy Directors, and manned by Senior Designs Engineers and Assistant Design Engineers and technical staff. The organization handles detailed designs of the various features of the dam and is expected to turn out 10,000 drawings during a period of 4-5 years.

The Directorate works in complete coordination with Central Water and Power Commission and foreign specialists as well as with Irrigation Research Institute. The total work has been suitably scheduled. The experience gained will be very valuable for future design work for high dams.

Construction and Plant Design Directorate

This Directorate is directed by Mr. Harvey Slocum. An Indian Joint Director of S.E's rank assists him. A separate S.E. acts as Administrative officer, who controls accounts, makes recruitments and posting of establishment, and deals with other connected correspondence. This enables the Joint Director to devote sufficient time to organise construction work. Due to contralisation of accounts and establishment, the chances of misappropriation and mis-application of labour have been minimised.

Procurement

Another officer of Superintending Engineer's rank does all the procurement of machinery, stores, spare parts; controls the workshops and running and maintenance of Thermal Powerhouse at Nangal. Surplus stores are also disposed of under his supervision.

Liaison and Transport Officers at Delhi and Bombay

These agencies have been set up to arrange licenses for the acquisition of stores, to arrange clearance of custom, and to despatch and receive personal effects of foreign specialists. They also arrange necessary bookings of Specialists, who are hired for various terms of employment at Bhakra.

Safety Department

The functions of this organization is to devise means in order to ensure as much safety as possible in the various operations of the construction.

Plant Design Section

The responsibility entrusted to this group is to design the plant required for the construction of the Bhakra Dam. The Section is supervised by a Foreign experienced Design Supervisor and a Senior Executive Engineer. The group is manned by junior specialists and Assistant Design Engineer, who all work themselves on the drafting tables.

Foreign Specialists

India has little technical experience in the handling and operation of heavy machinery or in the actual construction of a high dam, as this is the first high dam of any magnitude to be undertaken in India. This has actuated the employment of a sufficient number of foreign construction specialists to supervise erection, maintenance and operation of specialised equipment and to assist in the general planning and construction of specific jobs. Mr. Slocum, who has to his credit no less than 18 dams (high) in U.S.A. and who has been associated with scores of other dams, is employed on the Bhakra Dam. He is assisted by a number of experienced and trained foreign Specialists. The Specialists work in advisory capacity to the extent that lack of experience makes it advisable.

Liaison Engineer and Technical Attache at Washington

This agency attends to numerous matters of importance relating the recruitment of specialists, purchase of machinery and spare parts, consultations with design and construction experts in U.S.A. Also takes care of preliminary work for the recruitment and transportation, obtains quotations and makes purchases.

Directorate of Inspection and Control

Inspection Directorate exercises an independetn control on the quality of work, its execution according to specification. It controls the Nangal research laboratory for the testing of aggregate and designing the most economical mix for mass concrete.

Bhakra Dam Circle

This unit superintends the colonies and is responsible for the maintenance of buildings, their sanitation, lighting, water supply and other public amenities. The two diversion tunnels were also completed under the supervision of this Circle.

In the normal set up in the Irrigation Branch Punjab, there is an administrative unit under S.E., who controls a number of executive units in the charge of Executive Engineers. The works which are generally spread over large areas are got done through contractors.

In the Bhakra Nangal project this system could not be adhered to for the Bhakra Dam construction, due to its highly technical nature and the operations confined to limited space. Efficient supervision over mechanised operations is not only essential from the point of view of life of the machines but results in considerable savings both in time and machinery. The "Regional Control" was unworkable when within the same small working space a large number of different departments had to deal with different specialised functions.

Consequent to the Functional Control system, the various functions in the Bhakra Dam Administration have been centralised into four wings :

I. (*a*) Directorate of Bhakra Dam Designs.
   (*b*) Irrigation and Power Research Institute.
II. Directorate of Construction and Plant Design.
III. Directorate of Inspection and Control.
IV. Bhakra Dam Circle.

Bhakra Dam Designs Directorate

This deals with :—

(*i*) The alternative of Designing by Foreign Firms.
(*ii*) Board of Consultants.
(*iii*) Functioning of the Directorate.
(*iv*) Co-ordination with the Central Water and Power Commission.
(*v*) Division of Responsibility.
(*vi*) Schedule of Work.

Irrigation and Power Research Institute at Amritsar & Malikpur

Help on certain problems by actual tests on models is taken from this Institute.

Directorate of Construction and Plant Design

(*a*) Central Administrative Office is divided into three main Sections, namely, Administration, Accounts, & Personnel and Time-keeping.
(*b*) Procurement comprises of following units :
1. Procurement Division, Nangal, 2. Stores Division, Nangal, 3. Bhakra Warehouse Division, Bhakra, 4. Workshops Division, Nangal, 5. Electrical Division, Nangal, 6. Disposals, Nangal.
(*c*) Offices of Clearance and Personnel Officer, Bombay and Liaison and Transport Officer, Delhi.
(*d*) Safety Department.
(*e*) Labour Relations.
(*f*) Plant Design Section consists of :
1. Planning.
2. Aggregate processing.
3. Cooling Plant and Cement handling.
4. Structural Work.
5. Survey Section.
6. Checking Section.
(*g*) Foreign Specialists. Their functions are :
1. To advise the Joint Director and if it may be necessary the Director, in drawing up plans for the execution of particular jobs ;
2. to advise, on his own initiative and also when required, the Indian Head of Department regarding technical matters connected with execution of jobs.
3. to supervise, particularly from the technical point of view, the progress of work ;
4. to advise the Indian Head of Department on administrative matters to the extent that these are connected with the technical execution of work.
(*h*) The functious of the Liaison Engineer and Technical Attache at Washington.
1. Consultations about construction plans and design features of the Dam with the members of the Board of Consultants.
2. Consultations with the United States Bureau of Reclamation regarding Hydraulic experiments.
3, Preliminary work for the recruitment of Specialists.
4. Arranging of training facilities in U.S.A. for officers sent out from India on deputation.
5. Obtaining quotations and arranging purchases of emergent items of machinery.

The work of designing Bhakra Dam and Power Plants in detail for purposes of completing its construction has devolved on the Bhakra Dam administration. Previously in India all such projects have usually been contracted out for designing. This time a departure was made by the Punjab Government with the concurrence of the Government of India because the entire work of construction was to be executed departmentally.

This arrangement has proved to be eminently successful particularly on account of the complex nature of the design work involved in the special lay-out and foundation conditions which are a characterstic of the Bhakra Dam site.

The preliminary specification drawings had been made in Denver, Colorado, U.S.A. with the help of the International Engineering Co., Denver who had also consulted the U.S. Bureau of Reclamation. These specifications were, however, of quite a general nature and would have been suitable if the work was to be contracted out to some foreign contracting firm. Therefore it is usual to give a contract also for the engineering services involved in the design and drawing of the detailed features of the Dam. In the case of Bhakra Dam the foundation conditions were not capable of being predicted with exactness in the beginning. Perforce special features had to be excavated, examined, re-examinied and then taken care of in the designs. This procedure demanded that design changes could be possible at any stage of the execution of the work. If any foreign firm had been given this contract they would have always taken much more time for effecting changes and their bills would have mounted with heavy charge.

(*Continued on page* 75)

Progress of Construction

The work on the Bhakra Nangal Project is now entering the final critical phase. The Canal system, one of the largest in the world, was completed in July 1954, and its operation on a non-perennial basis using the run of the river according to India's share started right then. Its conversion into perennial, all the year round operation, now awaits the completion of the Bhakra Dam. Thereafter, in the entire region served by the Bhakra Nangal Project water will be "on the tap" as it were. That will bring a new era of insurance in the livelihood of the agriculturists.

The lined Nangal canal has now been in action for almost two years after its opening. It is a unique channel with certain reaches in embankments about 100 ft. high and certain other reaches in cuttings 120 feet deep. It has a depth of about 15 feet of flowing water when it is running full supply. There is also additional strain on it because of the heading up that has to be effected upstream of the Ganguwal and Kotla Powerhouses. Yet it has stood the strain of severe operation remarkably well. No doubt some small cracks have appeared in certain reaches and also there has been some subsidence of lining in one or two places, but that is not serious and the success of the specifications of lining has been proved beyond doubt.

One factor is outstandingly important and that is the efficiency of the external drainage. Engineers have felt that the life and durability of the Nangal Canal and Bhakra Canal lining are a direct function of the efficiency with which precipitation due to rain storms is drained off harmlessly. For this purpose, the old ideas of maintenance of earthen channels must change and higher financial provision must be made for the maintenance of lined canals. It is not doubted at all that this will be the conclusion eventually drawn by wise management.

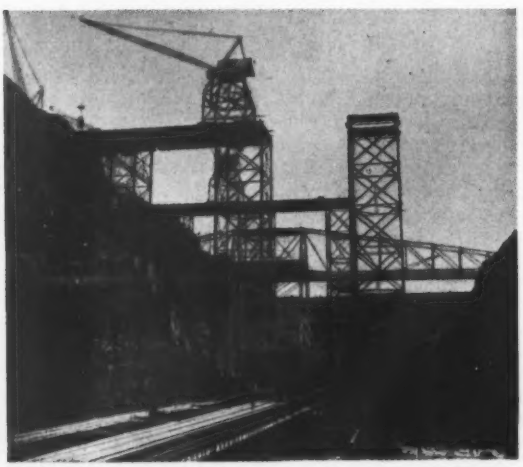
The Ganguwal and Kotla Powerplants are both in operation. Ganguwal has worked satisfactorily from the beginning of 1955. The load had already swung up to its full capacity. No sooner was Ganguwal energized that the Delhi load and the other backlog in the region demanded connections. The same is expected in respect of Kotla which has been energised since June of this year.

All eyes are now on the further completion of the Bhakra Dam which is being built "bucket-by-bucket". Giant cranes are in operation and are working in three shifts. One advantage of the assembly line operations is that the work is expected to go on round the clock all the 24 hours of every day of the next 3 years for all practical purposes. By middle of August 1956, over 3,32,000 cubic yards of cement had been placed.

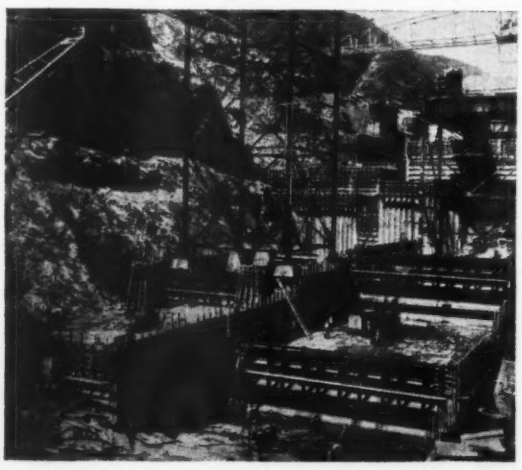
The Bhakra Dam is being visited by every diplomatic and other important visitor, who comes to this country. The concensus of opinion is that the job is very well laid out and has the best chance of success. Indian Engineers and other personnel have been trained around all the intricate mechanical operations.

The biggest Irrigation and Power Project of the 2nd Five Year Plan is still the Bhakra Nangal Project. In its wake and following its example many other projects have now been initiated in many other far-flung regions of this sub-continent. The emphasis still is "More Food, More Power."

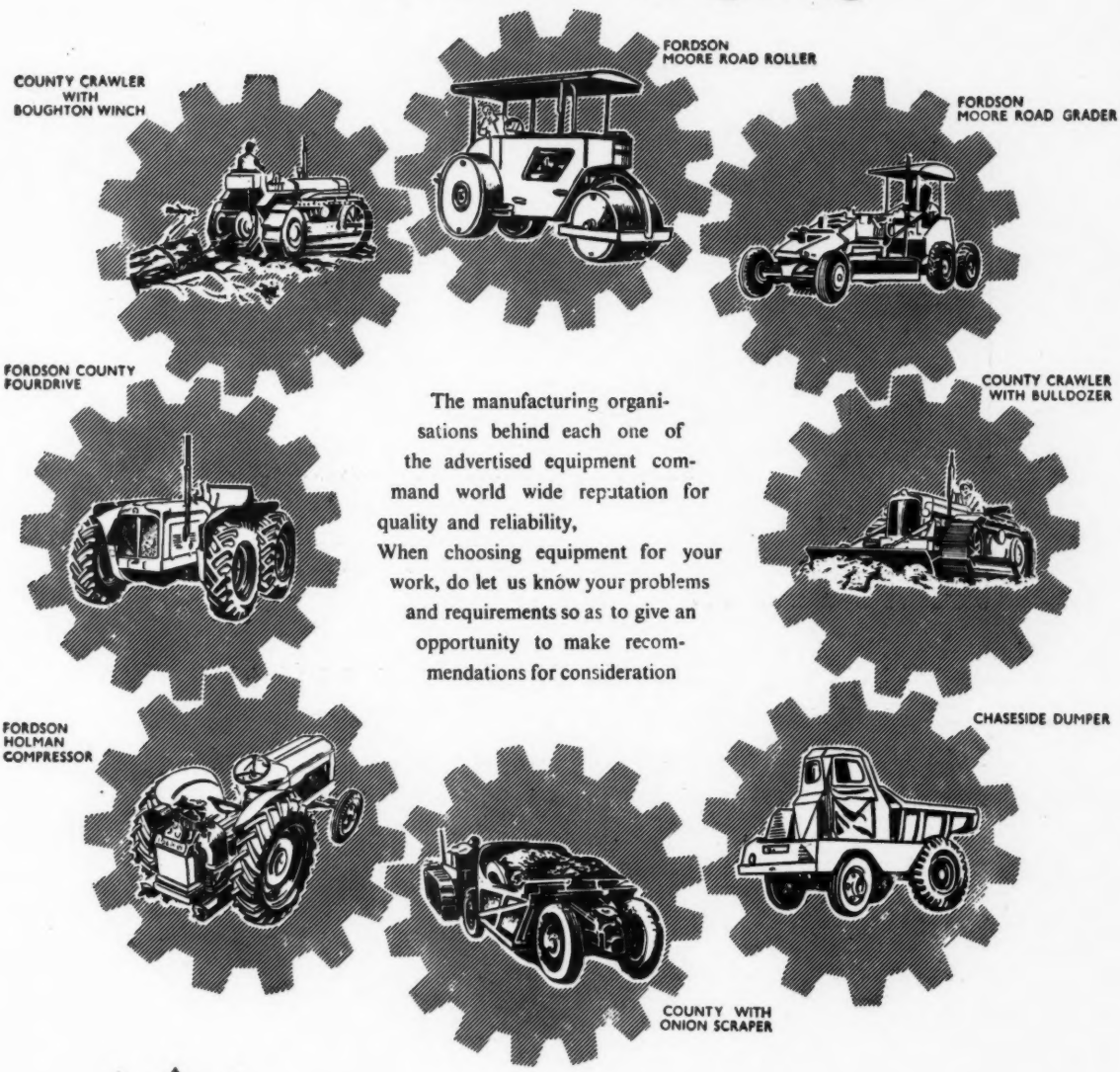
300 ft High Trestles being erected at Bhakra Dam



Concreting in progress at Bhakra, July, 1956



Famous Names Geared To India's Prosperity



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